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ORIGINAL ARTICLES.

Two New Crinoids from the Scottish Carboniferous Limestones, with Notes on the *Allagecrinidae*.

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I. INTRODUCTION.

WHEN dealing with the Scottish species referred to *Allagecrinus* (1932), it was a matter for regret that during the course of a long examination of the finer residue from washed shale from No. 1 Bed, Invertiel, among hundreds of tiny specimens the majority of which belonged to *A. scoticus* or *A. elongatus*, I had only been able to obtain two examples of the adult *A. austinii*.

In a postscript, however, to the above-noted paper, I recorded a further examination which resulted in the discovery of another five adults along with four intermediate forms. This examination showed that by concentrating on the coarser residue from the washed shale there was a good chance of finding greater numbers of the adult specimens. In the course of some months, therefore, I have adopted another method of washing shale from Invertiel, and so far have been

successful in finding over seventy individuals of the adult *A. austinii*. All these specimens are excellently preserved and exhibit some interesting features which are detailed further on. Opportunity is also taken to give a fresh diagnosis of the *Allagecrinidae*, with remarks on the species assigned to it.

When looking for the adult *A. austinii*, I was fortunate enough to find among the washed material two cups which clearly belonged to another form and, after cleaning, they proved to belong to *Catillocrinus*, a genus not hitherto recorded from British or European rocks. The species is also new and details are given herewith.

Along with this species it is proposed to describe a small crinoid crown which I found in washed shale from Carlops over four years ago. Since then I have made repeated examination of shale from this locality, at the same time keeping a lookout among the Invertiel material in the hope of finding more specimens, but so far have met with no success. The crown in question is quite unlike anything hitherto figured or described from Carboniferous rocks, and although in the absence of other examples certain points in its structure must remain obscure, it is deemed advisable to place it on record now. The generic name *Carlopsocrinus* is proposed for its reception and the specific appellation *bullatus* in allusion to the much swollen character of its basal ring.

II. Description of Species.

CATILLOCRINIDAE Wachsmuth & Springer.

Catillocrinus Shumard ex Troost.

(*a*) *Catillocrinus scoticus* n. sp.

Diagnosis.—Cup with 3 BB; basal ring one-third the total height of cup; no IBB; RR all unequal in width, LAR narrowest, Ant. R widest; from junction with basal ring LAR narrows to one-third or less of its width at top of cup; RPR a comparatively broad plate, narrowing at the top, with left shoulder on which lowest anal tube plate rests occupying about two-thirds of entire width; left shoulder of RPR slopes well down below level of LPR; all other RR widen out at top; cup expanding unequally with pronounced bulge on anterior side; lowest anal tube plate half the height of RPR; surface of plates finely granular; number of arms 30.

Material.—Two cups from No. 1 Bed, Invertiel.

Horizon.—Lower Limestone Group, Scottish Carboniferous Limestone Series.

Holotype.—J. Wright Colln. No. 2207; Pl. XIII, Figs. 1, 2, 7, and 8; Text-figs. 1, 2, 4, 5, 6, and 7.

Paratype.—J. Wright Colln. No. 2208; Pl. XIII, Fig. 3; Text-fig. 8.

Dimensions of Holotype.—Height of cup over all, 3 mm.; diameter at top, RPR to Ant. R., 4·3 mm.; narrowest diameter from LAR

to RAR, 3·9 mm.; diameter of base, 2·5 mm.; height of base, 1·2 mm.; width between sutures of RR at top: RPR 1·8 mm., LPR 2·5 mm., LAR ·8 mm., Ant. R 3 mm., RAR 2·3 mm.; number of arm-bearing facets on RR: RPR 1, LPR 9, Ant. R 12, RAR 7, LAR 1.

Dimensions of Paratype.—Height of cup over all, 3·5 mm.; height of base 1·5 mm.; number of arm-bearing facets on RR: RPR 1, LPR probably 9, RAR 7, LAR 1, Ant. R missing.

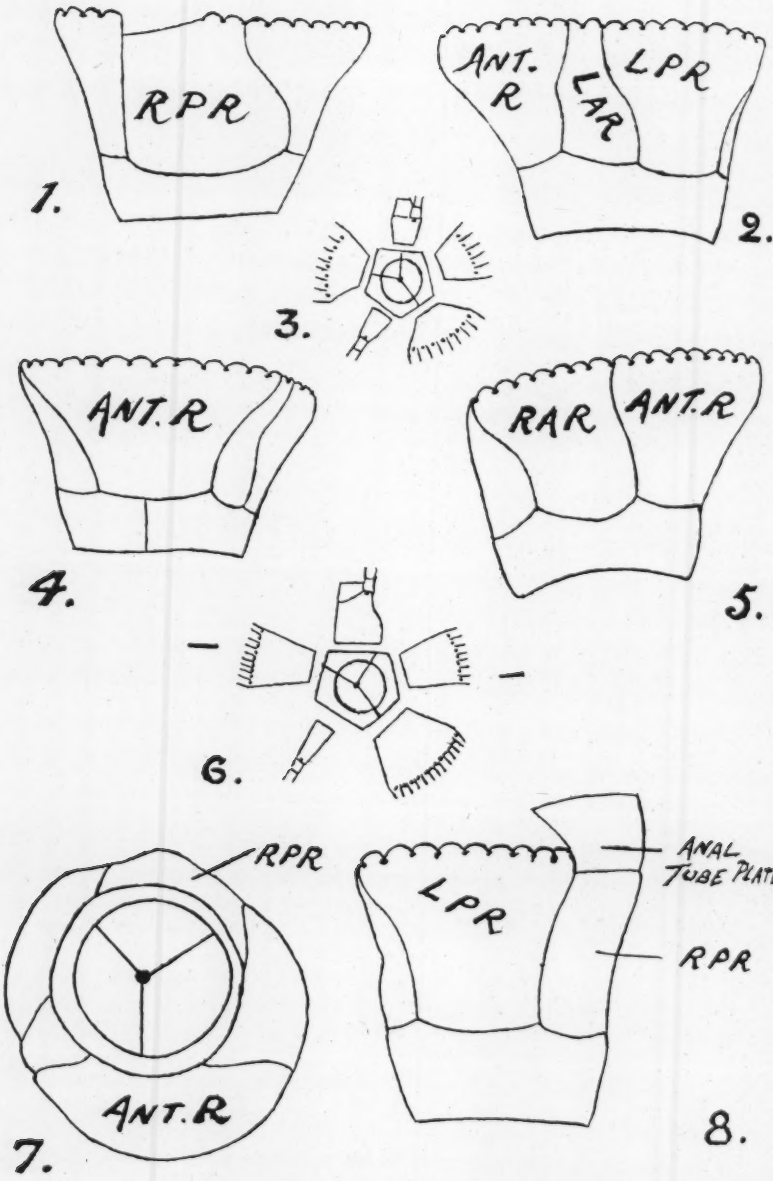
Affinities.—Near to *Catillocrinus carpenteri* Wachsmuth but differs in number of arms, greater height of cup and form and proportions of RR, especially RPR.

Remarks.

In Dr. Springer's comprehensive paper on the *Catillocrinidae* (1923), six species of *Catillocrinus* from American Carboniferous rocks are figured and described, as well as two species of *Mycocrinus* from Devonian strata in the Eifel. Reference is also made to the discovery of *Paracatillocrinus* by Professor Wanner in the Permian of Timor. The six American species of *Catillocrinus* appear to be all the recorded examples from the Carboniferous and it is therefore of special interest that the genus has now turned up in rocks of this age in Scotland.

Among the American forms, the nearest with which our cups can be matched is *C. carpenteri* Wachsmuth, originally placed under *Allagecrinus* by Wachsmuth (1882) but later removed to *Catillocrinus* by Dr. Springer (1923). On comparison, my first impression was that the Invertiel cups were identical with this American species which occurs on a parallel horizon, namely the lower part of the Chester group. Subsequent cleaning and examination, however, show that while agreeing in some respects there are certain differences in the Scottish form, the chief of which are: the greater height of the cup; the comparatively wide RPR and, more especially in the holotype, the manner in which this place narrows considerably at the top, i.e. in a reverse direction to that of *C. carpenteri* (Text-figs. 3 and 6); also the fact that the left shoulder of this plate slopes well down below the level of LPR.

In *C. carpenteri* (and *C. bradleyi*, which is a larger species than ours) it is emphasized by Dr. Springer that the first anal tube plate rests on the RPR at the same level as the arms, not sunken as in our species. One may also remark that in other American species, such as *C. turbinatus* and *C. wachsmuthi*, whose cups more or less resemble ours in shape but with radials different in form, the left shoulder of RPR extends beyond the line of the radials and has a raised process upon it. Another point of difference in our species is that the lowest anal tube plate appears to be relatively shorter, extending upwards for a distance which is only half the height of RPR. In *C. carpenteri* the lowest anal tube plate is about three-quarters the height of RPR.



FIGS. 1, 2, 4, and 5.—Side views of *Catillocrinus scoticus* n. sp. the holotype. Fig. 7.—Basal view of holotype. Fig. 8.—Side view of the paratype. Fig. 6.—Diagrammatic view of holotype for comparison with Fig. 3, which is a basal view of *C. carpenteri* after Dr. Springer. All figures × 11, except Figs. 3 and 6 which are approximately × 3.

Our specimens consist of cups only so that in *C. scoticus* the arms themselves, anal tube, and column are unknown. The distinctions in our species are therefore based chiefly on the form and proportions of the radials and, since in this respect *C. carpenteri* is the nearest, a diagram of the American species copied from Dr. Springer's figure (1923, pl. iv, fig. 8) is given for comparison. See Text-figs. 3 and 6.

One of our cups, No. 2207 J. W. Colln., is excellently preserved and taken as holotype (Pl. XIII, Figs. 1, 2, 7, and 8, Text-figs. 1 to 7), the other as paratype, J. W. Colln. No. 2208 (Pl. XIII, Fig. 3, and Text-fig. 8).

The paratype is somewhat crushed along the radials, and the Ant. R. is missing. In so far as preserved, it agrees with the holotype except in a few minor details. For example, the RPR does not appear to be quite so wide at the bottom where it joins the basal ring, but shows the same tendency to narrow at the top. The LAR, while much the same width at the bottom as in the holotype, is also rather narrower at the top, being only about one-quarter of the bottom width. The cup itself is higher with correspondingly higher basal ring, altogether a larger cup and probably more mature specimen. The granular ornamentation on the plates is if anything coarser than that of the holotype. In the paratype I find it difficult to be quite certain about the number of arm-bearing facets on LPR, since the depressions, ridges, and canals are obscure and confusing to count. There are, however, at least nine arm-facets as given in the dimensions of the cup, but it is possible there may be another facet close up against the anal tube plate which cannot be made out. If nine, as seems to be the case, this number agrees with that of the holotype. Since the Ant. R. is missing we cannot tell the number of arms here, but the facets may well have exceeded the number on the holotype, the paratype being a larger specimen altogether.

In the paratype the lowest anal tube plate is in position, in the holotype this plate is absent, but in all likelihood its form and proportions were much the same. On Pl. XIII, Fig. 8, which is a top view of the holotype, the sunken area on left shoulder of RPR into which this plate fitted is seen at the bottom of photograph as well as the arm-bearing facets on the radials. On the same Plate, Fig. 3, is seen the first or lowest anal tube plate in position on the paratype testing on the RPR.

To return to *C. carpenteri* and the comparative size of the radials. In the American species the RPR is scarcely two times wider than LAR and about half the width of RAR, whereas in *C. scoticus* the RPR is over two times wider than LAR and little less wide than RAR ; also in *C. carpenteri* RPR either widens out at the top or has nearly straight sides. In *C. scoticus* the tendency is in the opposite direction, i.e. to narrow at the top. The other radials are also somewhat different in proportion. In *C. carpenteri* the LPR and Ant. R are about the same in size and larger than RAR. In

C. scoticus the Ant. R is much larger than LPR and RAR, both being nearly equal in width. Our cups are also relatively higher. The height of *C. carpenteri* is given as 2·3 mm. ; that of our holotype is 3 mm. and paratype 3·5 mm.

The tripartite character of the base is well seen in the holotype, the sutures cutting from the centre to RPR, LPR, and Ant. R (Pl. XIII, Fig. 7, Text-fig. 7). In the paratype the base is not seen owing to the proximal columnal which is still adherent. Other views of the holotype may be seen on Pl. XIII, Figs. 1 and 2, and Text-figs. 1, 2, 4, and 5. These give a good idea of the shape of the cup, form, and proportions of the radials.

The number of arm-bearing facets on the radials in the holotype is 30. In *C. carpenteri* the number is variable, being given as 13–24. Possibly the number in *C. scoticus* is also variable, although one surmises within limits different from *C. carpenteri*. This is all the more likely when we consider the number of arms in the other American species, e.g. *C. bradleyi* 40–6, *C. shumardi* 20–5, *C. wachsmuthi* 24–39, *C. turbinatus* 37–53, and *C. tennesseae* 43–58. In the diverse characters of their cups, none of these species is comparable with *C. scoticus* except perhaps the first-named, *C. bradleyi*, but it is much larger and differs also in other ways. The nearest in actual size of the cup, although quite different in the form and proportion of the radials, seems to be *C. wachsmuthi* with height of 3·5 mm. and arms 24–39. Possibly these are about the limits in number we should expect to find in *C. scoticus*, but until more specimens are forthcoming we cannot be certain.

Since finding the two cups herein described I have made additional examination of washed shale from Invertiel in the hope of obtaining other examples, but have so far failed. The species seems to be very rare. At the same time, I imagine that in the past cups of the *Catillocrinid* type have been many times overlooked in the Scottish and English Carboniferous limestones and shales. Among multitudes of crinoid ossicles it is, of course, not easy to pick out cups of the type noted, more especially when in a shaly condition such cups are barely distinguishable from the stem ossicles among which they occur. Such a cup as the holotype, for example, with the interior filled with matrix and looked at from above, has at a first glance just the appearance of an ordinary columnal. It is hoped, however, that this note will draw attention to the desirability for a stricter discrimination among crinoidal debris and that before long more specimens of this interesting crinoid genus will be found.

Carlopsocrinus n.g.

(*b*) *Carlopsocrinus bullatus* n. sp.

Diagnosis.—A small dicyclic crinoid with, at the base, a greatly swollen, button-like, knob or ring, the upper rim of which projects slightly beyond the BB ; 5 small BB ; 5 large RR about $2\frac{1}{2}$ times

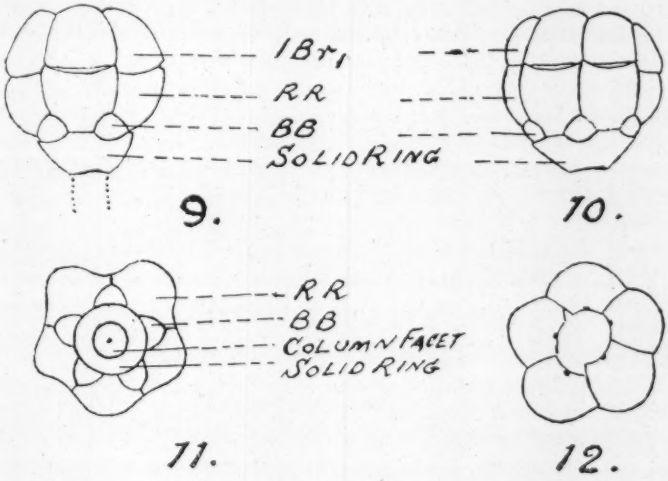
wider and higher than BB ; no anal or inter-radial plates ; arms 5, consisting of a single primibrach in each ray but possibly succeeded by another IBr, making 2 to the ray ; IBr_1 about same size as RR.

Material.—One crown from Carlops.

Horizon.—Lower Limestone Group, Scottish Carboniferous Limestone Series.

Holotype.—J. Wright Colln. No. 2209; Pl. XIII, Figs. 4, 5, and 6, Text-figs. 9, 10, 11 and 12.

Dimensions of Holotype.—Height of crown over all 2·3 mm. ; greatest width across RR 2·3 mm. ; narrowest 2 mm. ; height of the button-like basal ring ·7 mm. ; diameter of ring at top 1 mm., at bottom ·5 mm. ; diameter of column facet ·4 mm.



FIGS. 9 to 12.—*Carlopsocrinus bullatus.* Figs. 9 and 10.—From the side. Fig. 11.—From below. Fig. 12.—From above. All approximately × 11.

Remarks.

This handsome little crinoid is very difficult to place since there seems nothing quite like it described or figured from Carboniferous rocks ; hence I have long hesitated from dealing with it in the hope that other specimens would turn up to enable us to get more precise details regarding its structure. Since there seems a poor prospect of getting additional specimens at present, I am now placing the specimen on record. The diagnosis given above must, however, be taken as provisional only, and at best very inadequate since it is impossible to state with any certainty the systematic position of the crinoid or the family to which it belongs.

As may be seen from Pl. XIV, Figs. 4, 5, and 6, and Text-figs. 9, 10, 11, and 12, our specimen consists of a complete crown with a greatly enlarged ring at the base. This ring is in the form of a thick button.

At the bottom it is ·5 mm. in diameter, and widens out at the top to 1 mm., where it slightly overlaps the basals. Its height is ·7 mm. On the bottom the facet for the attachment of the column, circular in area and ·4 mm. in diameter, is well seen, but the central region of the facet itself is filled with matrix which is difficult to remove without risk, so that the details of the facet are obscure. There are no indications of sutures running across the base to give a clue to its structure. Had another specimen been available one might have ground down the base in an endeavour to trace this. The button-like ring here described occupies the position of the IBB in a normal Palaeozoic crinoid. Above this are five comparatively small basals, and alternating with these are five large radials, curving outwards and meeting all round the periphery of the cup with no anal or inter-radial plates. The arms are very simple. Upon each radial is a single brachial making one primibrach only in each ray. These IBr are much about the same size as the RR, and are of fairly uniform dimensions. One, however, is noticeably smaller than the others, but I am unable to specify its position. No other brachials succeed these. All five radials curve over gently towards the top, but their tips do not quite meet. The outward and inward curve of the brachials, however, coincides with the downward and inward curve of the radials ; thus if we imagine that the swollen ring is absent the outline of the specimen forms an almost complete circle.

When the crown is looked at from above there is a gap between the tips of the brachials, and one notices the end of the food grooves at the termination of each arm (Text-fig. 12). Possibly there was an additional primibrach on each arm, i.e. making two IBr to the ray, which in the living crinoid closed entirely over this gap. If so, these IBr_2 must have been very small. In the gap itself, down below the level of the arm tips, is a structure which looks like the remains of a ventral sac or oral arch. I cannot be certain about this, since I have been unable to clean out the interior without injury to the specimen. That it is probably more than the usual limestone matrix filling up the inner cavity seems indicated by a somewhat circular aperture or depression, possibly the anus, near the centre of the structure down between the arms.

In trying to determine the systematic position of our crinoid we get no help from the radial facets which are completely hidden. The central area of the outer rims of the radials slants outwards and the lower rims of the primibrachs at this point also have an outward slant, so that in outline there is a notch here which may be seen in the side views. No facets are visible.

The question arises, where are we to place the crinoid ? To this I can find no satisfactory answer at the moment. Some of the characters noted above suggest at first sight that our little crinoid may be a young example of a form related to *Cupressocrinus*, which is, of course, a Devonian genus. The heavy primibrachs in our species, although limited in number and the symmetrical cup, have

something in common with that genus. In the symmetry of its cup our species also resembles *Erisocrinus*, although the basals in this genus as well as in *Cupressocrinus* are proportionally larger. These and other forms, of course, such as *Stemmatocrinus*, etc., do not have anything in the nature of a swollen basal ring, but have more or less normal infra-basals. On the other hand, our species has some resemblance to *Calycocrinus spinosus* Wanner, a flexible crinoid from the Permian of Timor, which has a ring of large infra-basals (pl. iii, figs. 13 and 15, in Wanner, 1924). The basals here, however, are also relatively large, whereas in our species these plates are relatively small. None of these comparisons is satisfactory.

How are we to interpret the swollen basal ring in *Carlopsocrinus* ? There seem to be three alternatives : (1) as the much swollen and fused IBB only ; (2) as the proximal columnal and IBB fused together, a " centro-dorsal " as in the Jurassic *Thiollericrinus* ; and (3) as the swollen proximal columnal only covering IBB, which in this case must be very small. In the absence of other specimens none of these explanations is capable of proof, and the Palaeozoic age of *Carlopsocrinus* is not favourable to (2) and (3). As to (1), we should have expected the basals to be considerably larger, not dwarfed as in our form. The matter can only be left in this unsatisfactory stage at present.

III. Notes on the *Allagecrinidae*.

In the series of washings referred to in the introduction to this paper, seventy-nine specimens of the adult *Allagecrinus* were found. Nearly all are cups only except two which have the almost complete stem attached (Pl. XIV, Figs. 5 and 7). The great majority have the proximal columnal still adherent to the basals ; several have three or more columnals, but in four no columnals are attached to the base so that this part of the cup can be examined from below. These four specimens show very clearly that the base is tripartite, the sutures, as in *Catillocrinus*, running from the central canal to RPR, LPR, and Ant. R. Two of these cups are shown on Pl. XIV, Fig. 6, and Text-figs. 13 and 14.

In a few of the specimens some of the primibrachs are in position on the radials, but none show a complete circle. It is therefore not surprising that the oral arch is not present in any of the specimens, since it is my experience among the adult specimens that if the circle of primibrachs is not intact, with perhaps the exception of the anterior primibrach, the arch is rarely found in the fossil. After cleaning away the matrix in every one of the cups, only one or two were found in which traces of the orals could be detected well down in the cavity of the cups ; as if the structure had fallen in there on the death of the crinoid. Occasionally the lowest plate of the anal series is found in position on left shoulder of RPR. On Pl. XIV, Fig. 8, is shown a cup of this type and for comparison Fig. 11 on the same

plate shows another cup of about the same size with the anal plate absent. The low basal circlet is also well seen in the figures.

NUMBER OF ARMS IN THE 79 SPECIMENS.

2	have	10	arm-bearing facets	on	RR	plus anal series.
13	„	9	„	„	„	„
26	„	8	„	„	„	„
24	„	7	„	„	„	„
5	„	6	„	„	„	„
9	„	5	„	„	„	„

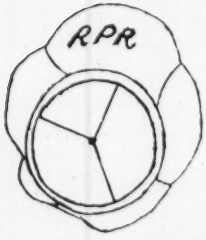
Total 79

HEIGHT OF CUPS.

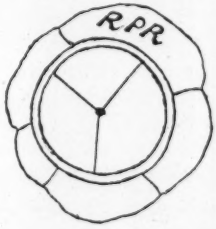
In the	5 armed.	Lowest 1·9 mm.	Highest 2·5 mm.
„	6 „	„ 2 mm.	„ 2·2 mm.
„	7 „	„ 1·8 mm.	„ 2·8 mm.
„	8 „	„ 2 mm.	„ 2·9 mm.
„	9 „	„ 2 mm.	„ 3 mm.
„	10 „	No data crushed.	

LONGEST AND SHORTEST DIAMETER OF CUPS AT TOP ACROSS RR.

In the	5 armed.	2·9 mm. × 2·7 mm. × 2·4 mm. × 2·2 mm.
„	6 „	3 mm. × 2·6 mm.
„	7 „	3 mm. × 3 mm. × 2·5 mm. × 2·3 mm.
„	8 „	3·9 mm. × 3·5 mm. × 2·5 mm. × 2·9 mm.
„	9 „	3·8 mm. × 3·4 mm. × 3 mm. × 3 mm.



13.



14.

FIGS. 13 and 14.—*Allagecrinus austinii* Carp. & Eth., to show the tripartite base. Author's Collection from No. 1 Bed, Invertiel.

In some cups there is little difference in the diameter at top, in others there is a bulge to the posterior and the longest diameter is always in this direction, i.e. from RPR to Ant. R and shortest from LAR to RAR.

POSITION OF AXILLARY RADIALS.

In the	5 armed.	None.
„	6 „	LPR.
„	7 „	LPR, RAR.
„	8 „	LPR, RAR, Ant.R.
„	9 „	LPR, RAR, Ant.R (3).
„	10 „	LPR (3), RAR, Ant.R (3).

No special search was made for young or intermediate examples, the finer residue from the washed shale being laid aside for future examination. I have therefore at present little to add to what has already been published about the young forms. On Pl. XIV, Figs. 4 and 10, however, are shown two of the intermediate specimens referred to in the postscript to my previous paper (1932). Text-fig. 15 is a sketch of the top of the young specimen shown on Fig. 4 of Pl. XIV. Here the position of the undeveloped radials, anus, and hydropore on posterior oral may be noticed. In this specimen the suture cutting the basals at foot of LPR is also seen. The base does not have the proximal columnal attached, and although difficult to make out, the base seems to be tripartite as in the adult specimens.

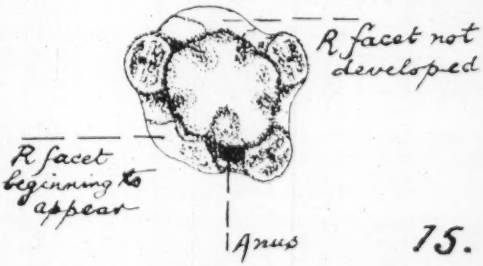


Fig. 15.—*Allagecrinus austinii.* Carp & Eth., young specimen to show position of undeveloped radial facets, anus, etc. Author's Collection from No. 1 Bed, Invertiel.

When going over the specimens referred to *Allagecrinus scoticus* in my former paper I could not help noticing that there was a good deal of variation in the shape of the calices. This is just what one would naturally expect among nearly a thousand specimens. The predominant shape is, of course, the globose or sub-globose form which I have illustrated (1932), but there there is a somewhat different and persistent variety which is met with. This variety, now named *contractus*, is much narrower and considerably less globose when compared with calices of similar size. On Pl. XIV, Fig. 1, is shown a typical specimen of the variety alongside Fig. 2, which is a calyx of a normal *A. scoticus* of nearly the same height. On Fig. 3 of this Plate is also shown a normal example of *A. elongatus*. The variation in shape in this species is not so marked and when calices do differ from one another it is usually due to the irregular development of the arm facets on the radials. When a radial is axillary it swells out at the top. In the figured specimen the radials on left and right are axillary, the one in the middle bears only one arm.

In my previous communication, when referring *A. scoticus* and *A. elongatus* to *Allagecrinus*, I considered it likely that these two species would ultimately be placed under another genus, and I have now come to the conclusion that they should be transferred to

Kallimorphocrinus, the genus proposed by Mr. J. Marvin Weller for his American forms. To this genus apparently also belong all the Timor species described under *Allagecrinus* by Professor Wanner, except *A. dux*, and the Russian species described by Professor Yakovlev.

In recent years our knowledge of the distribution and number of species assigned to the family *Allagecrinidae* has been considerably increased, notably by Professor Wanner in the Permian of Timor (1929, 1930), Professor Yakovlev in the Permo-Carboniferous of the Urals (1927, 1930), and by Mr. J. Marvin Weller in the Carboniferous of the United States (1930). Including the species *A. americanus*, discovered by Rowley in the U.S.A. in 1895, transferred mistakenly, I think, to *Hybochilocrinus* by Mr. Weller in 1930; the type species *A. austinii*, described by Carpenter and Etheridge in 1881 when the family was instituted, together with the four additional species described by myself in 1932, the total number now referred to this family is thirty species and five varieties.

The Timor, Russian, and American species, excluding *A. dux* and *A. americanus*, have much in common, i.e. they have a low basal circlet, more or less equal radials, and an oral arch either pyramidal, domed, or rosette in form. There is no anal opening into the calyx, but most if not all seem to have a hydropore on posterior oral. To this category belong the two Scottish species, *A. scoticus* and *A. elongatus*, now placed under *Kallimorphocrinus*. It is true that the American species of this genus have radial facets in which the position of the axial canal is somewhat different from the Timor, Russian, and Scottish forms, but in discussing this matter with Professor Wanner he reminds me that the position of this canal is not always in exactly the same place in the radials of even the same species, as e.g. *A. yakovlevi* Wanner (figs. 2 and 8, pl. i, in Wanner, 1929); and as regards the orals, he tells me he has got a specimen of *A. quinquibrachiatus* Wanner, from Timor, in which the usually convex surfaces of the oral arch are concave. These structures, therefore, seem to be variable in one and the same species. Because of their close similarity in other directions, it seems reasonable to group all the above species under *Kallimorphocrinus*.

Turning to *Allagecrinus sensu stricto*, the chief features in which it differs from all the preceding are the anal opening into calyx and the arm-like series of anal plates correlated therewith. To this category belong *A. austinii*, the genotype, *A. garpelensis*, *A. biplex*, *A. dux*, and probably also *A. americanus*. All these have a comparatively low basal circlet with unequal radials and as far as known an oral arch which is flat-topped and rosette in form. Clearly these species form a group by themselves. In the present state of our knowledge, therefore, I feel disposed to define the family thus:—(*a*) with anal opening into calyx and arm-like series of anal plates; and (*b*) with no anal opening into calyx and no anal plates.

ALLAGECRINIDAE Carpenter & Etheridge (emend.).

(*a*) Monocyclica Inadunata with low circlet of 3 BB; 5 RR unequal in width, any of which in the adult may be axillary except LAR; arms in adult 5 to 10; sporadic and irregular in young; oral arch in form of flattened rosette; arm-like series of anal plates on left shoulder of RPR; anal opening into calyx at prox. end of post. O; hydropore on post. O. Genus *Allagecrinus* Carp. & Eth.

(*b*) Monocyclica Inadunata with low basal circlet, sutures rarely visible; 5 RR of nearly equal width; arms 5 to 10 or more; oral arch pyramidal, domed, or rosette in form; no anal opening into calyx; hydropore on post. O; arms absent or sporadic in young. Genera, *Kallimorphocrinus* Weller, probably also *Aidemocrinus* Weller.

The following seem to be all the known species belonging to the *Allagecrinidae*.

(*a*) *Allagecrinus* Carp. & Eth.

A. austinii Carp. & Eth.
A. garpelensis Wright.
A. biplex Wright.
A. dux Wanner.
A. americanus Rowley.

(*b*) *Kallimorphocrinus* Weller.

K. astrus Weller.
" var. *typus* Weller.
" " *intermedius* Weller.
" " *pyramidalis* Weller.
K. piasaensis Weller.
K. lilius Weller.
K. indianensis Weller.
K. vanpelti Weller.
K. infacetus Weller.
K. sp. Weller.
K. pocillus Weller.
K. illinoisensis Weller.
K. knighti Weller.
K. expansus Weller.
K. yakovlevi Wanner.
K. inflatus Wanner.
K. acutus Wanner.
K. procerus Wanner.
K. quinquilobus Wanner.
K. indoaustralicus Wanner.
K. excavatus Wanner.
K. quinquibrachiatus Wanner.
K. ornatus Wanner.
K. scoticus Wright.
K. scoticus var. *contractus* Wright.
K. elongatus Wright.
K. multibrachiatus Yakovlev.
K. uralensis Yakovlev.
" var. *nodocarinatus* Yakovlev.
K. donetzensis Yakovlev.
Aidemocrinus odiosus Weller.

IV. Diagnosis of the Scottish Species.

(*a*) *Allagecrinus* Carpenter and Etheridge.

Annal. and Mag. Nat. Hist., **5**, vii, 1881, 281–298.

Allagecrinus austinii Carp. and Eth. (emend.).

Geol. Mag., LXIX, August, 1932, 337–366.

Diagnosis.—Cup consisting of low circlet of 3 BB; 5 RR, five to six times higher than BB; RR unequal in width, LAR being narrowest and Ant. R somewhat wider than the other three RR; RAR, Ant. R, and LPR may be axillary; arms in adult 5 to 10; oral arch in form of flattened rosette, consisting of five O of nearly equal size, post. O being largest; hydropore on post. O may be

present but invisible on older specimens and probably represented by a tubercle on young and intermediate examples; anal opening into calyx at prox. end of post. O; RPR differentiated, the left shoulder sloping well below the level of LPR; right shoulder of RPR not axillary; in young stages arms develop sporadically; plates of arch and calyx deeply pitted in young but in older specimens is represented by fine granular ornamentation; in mature specimens plates are smooth; stem vermiform, consisting of 10 or more columnals. Height of cup up to 3 mm.

Allagecrinus carpelensis Wright.

Geol. Mag., LXIX, August, 1932, 346.

Diagnosis.—Cup with heavy plates and RR much swollen at their upper margins, which characters distinguish this species from the former. Height of cup up to 3 mm.

Allagecrinus biplex Wright.

Geol. Mag., XIX, August, 1932, 348.

Diagnosis.—A minute species with low basal circlet; RR twelve to fourteen times higher than BB; right shoulder of RPR axillary and bears two arms; anal series on left shoulder; oral arch low; surface of plates smooth or finely frosted. Height of cup up to 1·5 mm.

(*b*) *Kallimorphocrinus* Weller.

Report of Invest. State Geol. Surv. Urbana, Illinois, 1930.

Kallimorphocrinus scoticus Wright.

Allagecrinus austinii Carp. and Eth. (pars.).

Allagecrinus scoticus Wright.

Geol. Mag., LXIX, August, 1932, 349.

Diagnosis.—A minute species; calyx globose or subglobose; low basal circlet, sutures invisible; 5 nearly equal RR, fifteen to sixteen times higher than BB; arms 5; oral arch of five O, dome shaped, with hydropore in form of knob situated well up towards distal end of post. O; no anal opening into calyx; in young radial facets develop sporadically; stem vermiform; plates finely frosted. Height of cup up to 1·5 mm.

Kallimorphocrinus scoticus var. *contractus*, new var. (Pl. XIV, Fig. 1.)

Diagnosis.—As above species, but with considerably narrower calyx.

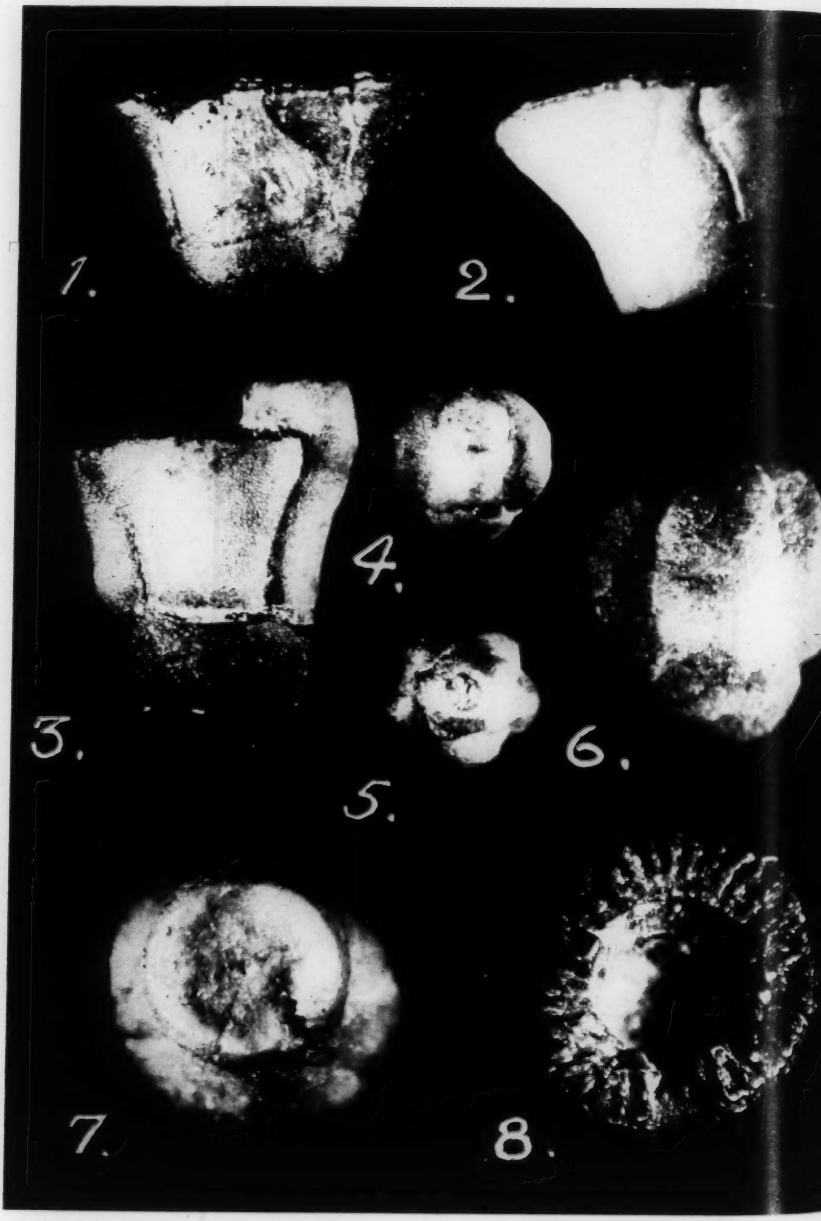
Kallimorphocrinus elongatus Wright.

Allagecrinus austinii Carp. and Eth. (pars.).

Allagecrinus elongatus Wright.

Geol. Mag., LXIX, August, 1932, 352.

Diagnosis.—A minute species with elongated calyx and low basal circlet, sutures invisible; 5 nearly equal RR seven to ten times



J. Wright photo.

Catillocrinus scoticus, sp. nov. Invertiel; *Carlopsocrinus bullatus*, n.g. and
Carlops.

To face p. 207.]

higher than BB ; oral arch in form of flattened rosette ; hydropore on post. O ; arms in adult 5 to 8, in young develop sporadically ; plates porous or honeycombed ; no anal opening into calyx. Height of cup up to 1·7 mm.

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EXPLANATION OF PLATES XIII and XIV.

Plate XIII.

Figs. 1, 2, 3, 7, and 8. *Catillocrinus scoticus* n. sp. from No. 1 Bed, Invertiel. Figs. 1, 2, 7, and 8 holotype, author's collection No. 2207. Fig. 3, paratype, author's collection No. 2208. Fig. 1, posterior view of cup showing RPR ; on the right the RAR has a fracture which runs downwards to meet the suture between RPR and RAR ; the true suture between RAR and Ant.R is seen on the extreme right. Fig. 2, Ant.R on left and LPR on right, LAR in centre. Fig. 3, LAR on left, LPR in centre, and RPR on right, with first anal tube plate in position ; the suture line between the latter and RPR can be seen about 4·5 mm. below the top of LPR. Fig. 7, view of cup from below showing the basal ring, proportionate size of RR, etc. ; the sutures cutting the BB from axial canal to Ant.R and RPR can be detected. Fig. 8, view of the cup from above, showing sunk area for lowest anal tube plate, radial facets, etc. All × 11.

Figs. 4, 5, and 6. *Carlopsocrinus* n.g. from Carlops, author's collection No. 2209. Fig. 4, view from side. Fig. 5, from below. Fig. 6, from the side, showing gap between IBr_1 at top on left-hand corner. Figs. 4 and 5, × 11 ; Fig. 6, × 17.

PLATE XIV.

FIG. 1. *Kallimorphocrinus scoticus* var. *contractus* Wright.
FIG. 2. A normal specimen of *K. scoticus* Wright.
FIG. 3. *Kallimorphocrinus elongatus* Wright.
FIG. 4. *Allagecrinus austinii* Carp. & Eth. Intermediate specimen with partly developed R facet on left and fully developed RR in centre and on right, RPR in middle.
FIGS. 5 and 7. *Allagecrinus austinii* Carp. & Eth. Side views with stem attached.
FIG. 6. Cup of the same species from below. Shows the basal ring and sutures cutting from centre to Ant.R, RPR, and LPR.
FIGS. 8 and 11. Cups of the same species from posterior showing the relative height of BB, sloping left shoulder of RPR, etc. In Fig. 8 the lowest anal plate is in position; in Fig. 11 it is absent.
FIG. 10. Intermediate example of the same species; RPR on extreme right.
FIGS. 9 and 12. *Allagecrinus garpelensis* Wright. Fig. 9 from posterior. Fig. 12, the same specimen from the top showing plates of oral arch in position sinking down to posterior; the lowest anal plate is conspicuous at bottom of photograph and is much wider than the IBr_1.
FIGS. 13 and 14. *Allagecrinus biplex* Wright. From posterior. In Fig. 13 the lowest anal plate is in position, in Fig. 14 it is wanting.

Figs. 1, 2, 13, and 14 from Carlops; Figs. 9 and 12, from Muirkirk. All others from No. 1 Bed, Invertiel. All figures × 11, except Figs. 1, 2, 3, 4, 10, 13, and 14, which are × 17.

The Glacial Deposits of Gower.

By T. NEVILLE GEORGE, D.Sc., Ph.D., F.G.S.

(PLATE XV.)

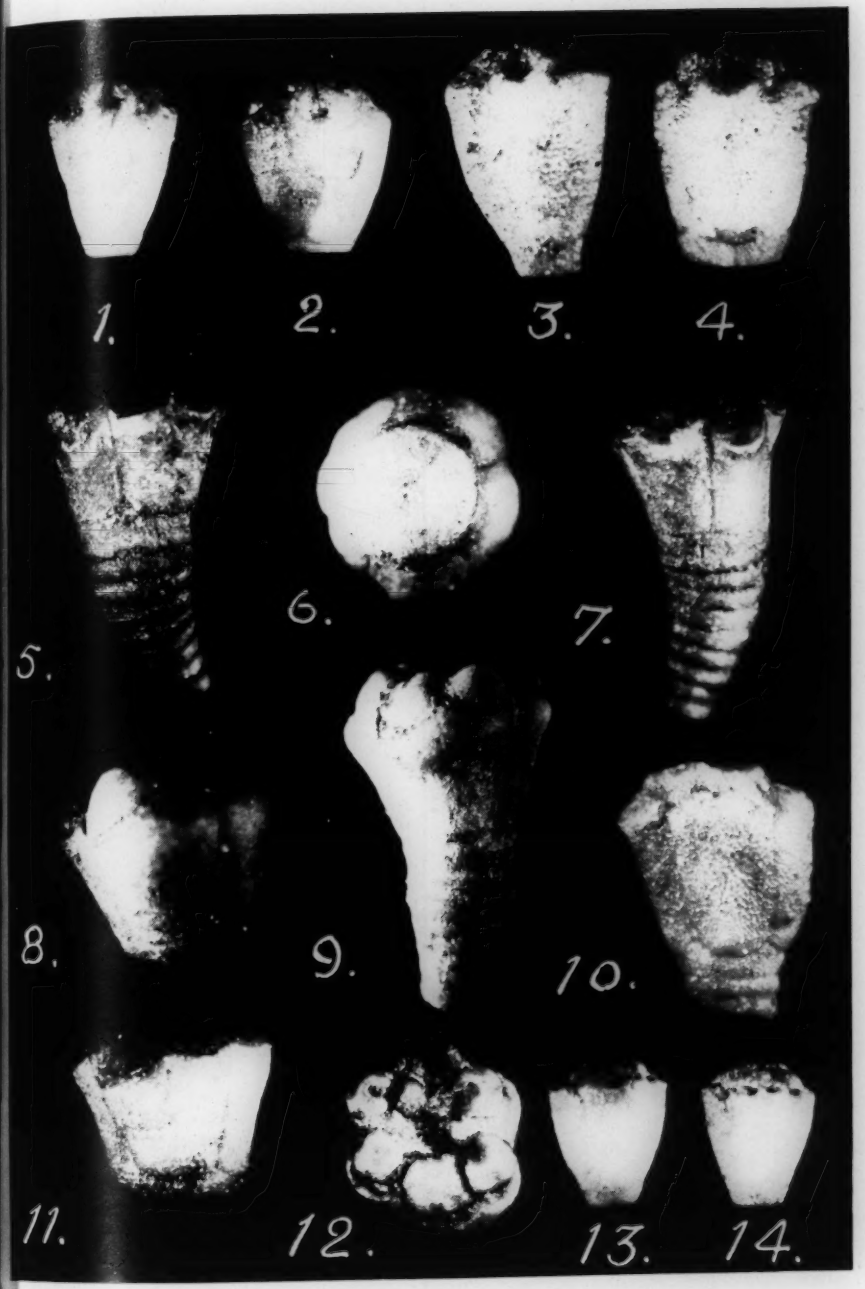
I. INTRODUCTION.

A GENERAL description of the drifts of Gower has been given in the memoirs of the Geological Survey,[1] in which, however, no distinction was made between deposits of different ages. But it has long been known that there are at least two series of Glacial deposits in South-Western Britain, though until recently their relative extents were only surmised: in South Wales the relations of the drifts have been determined only within the last few years.[2] As a consequence of this recent work it is clear that the Newer Drift does not extend into Gower much beyond the Sketty-Fairwood-Mumbles neighbourhood, and while the margin of this Newer Drift as determined by Charlesworth may be questioned in detail, especially further west along the Towy Valley,[3] yet it is at least certain that the greater

[1] "The Country around Swansea": *Mem. Geol. Surv.*, 1907, 136. "West Gower and the Country around Pembrey": *Mem. Geol. Surv.*, 1907, p. 39.

[2] J. K. Charlesworth, "The South Wales End-Moraine": *Q.J.G.S.*, lxxxv, 1929, 346, and pl. xxi. For a local note see T. N. George, "Pleistocene Deposits at Mayals": *Proc. Swansea Sci. and Field Nat. Soc.*, i, pt. v, 1931, 142.

[3] Though it must be recognized that the common northern source of the two drifts militates against the possibility of determining precisely their respective limits.



J. Wright photo.

Kallimorphocrinus scoticus, K. elongatus, Allagecrinus austinii, A. garpelensis, A. biplex.

[To face p. 208.

part of Gower is (or was) covered by Boulder Clay and gravels of the older drift. The general absence of deposits characteristic of terminal moraines, the "mature" topography, and the great amount of erosion that the drift has suffered are sufficiently distinctive, even apart from the extensive mounds of sand and gravel that mark the boundary of the Newer Drift further east.

The remarks that follow refer almost exclusively to the earlier drift, and to the deposits of head and loam that are associated with the more truly ice-borne gravels.

I am indebted to several friends for assistance in the work. In particular, Professor A. E. Trueman has accompanied me in the field and discussed various points with me.

Dr. H. H. Thomas, F.R.S., has examined a large number of my erratic igneous rock specimens; without his aid I should have remained in ignorance of the derivation of the majority of them, and the discussion of the relations of the Western Drift has gained considerably as a result of his interest.

II. The Character and Distribution of the Glacial Deposits.

Nearly the whole of the 200-foot plateau of Gower bears some evidence of having been glaciated, and a glance at the geological map shows that still the greater portion supports more or less thick deposits of drift. These, however, are very largely obscured from view by vegetation, and the clearest evidence concerning ice-movement and content is to be obtained from the coast sections, especially along the southern and western shores of the Peninsula. A detailed description of some of the principal exposures follows. It should be prefaced by the remark that there is little or no true Boulder Clay in Gower, and the usage of that term by the officers of the Geological Survey gives it a latitude that is unwarranted. The drifts consist almost wholly of sand and gravel, and possess the characters of a ground moraine.

(*a*) *Rams Tor and Rotherslade.*

On the mainland opposite Rothers Sker,[1] the pre-Glacial *Patella* Beach is overlain by a variety of deposits. In the cliff north-east of the island the shelly shingle is succeeded by some 3 feet of fine-grained fox-red sandy loam, presumably the "blown sand" of Tideman and the Geological Survey. It bears little resemblance to the obvious blown sands that occur elsewhere along the coast, as between Heatherslade and Shirecombe,[2] and partakes more of the nature of the sands that are associated with the head at such

[1] The sketch-map showing the distribution of igneous erratics in West Gower (p. 224) gives the situation of most of the localities of that district. For East Gower, see T. N. George, "The Quaternary Beaches of Gower": *Proc. Geol. Assoc.*, xliii, 1932, p. 292.

[2] Ibid., p. 310.

places as Kilboidy, Fall, and Three Cliffs Bay. This sand diminishes in thickness westwards and passes laterally into loosely-packed uncemented head containing angular fragments of Carboniferous Limestone in a loamy matrix almost identical with the fox-red sand. The head reaches a maximum thickness of about 5 feet, and itself interdigitates with Boulder Clay : in one very clear section (Fig. 1), about 300 yards north-east of Rothers Sker, the sequence is :

(iii) Coarse gravel, devoid of local Avonian material.
(ii) Uncemented loamy head, the fragments being composed almost wholly of Carboniferous Limestone.
(i) Coarse gravel, as (iii).

The Glacial gravel in places completely overrides the underlying head and sand, and rests directly on the pre-Glacial *Patella* Beach, or on the ancient Beach platform.

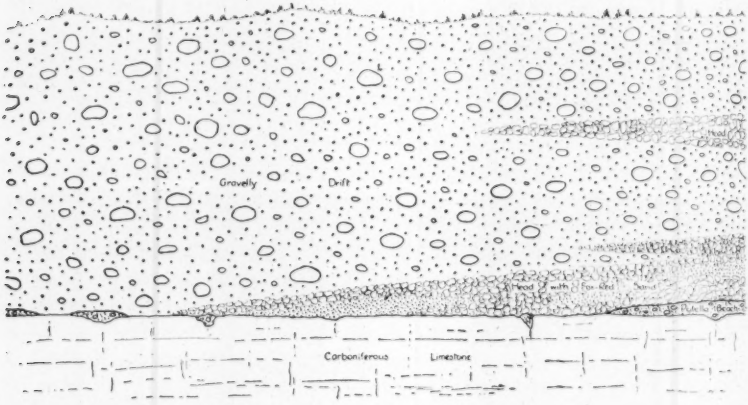


Fig. 1.—Diagrammatic section of the deposits displayed in the cliffs on the mainland opposite Rothers Sker. The interdigitation of relatively "pure" Limestone head with Limestone-free Glacial gravel is well displayed, the whole resting on an eroded surface of the *Patella* Beach platform, which carries fragments of shelly shingle.

The gravel is a very crudely stratified deposit with abundant pebbles and boulders of Coal Measure sandstones and ironstones (one erratic measures $5 \times 3\frac{1}{2} \times 3$ feet) ; quartzites and quartz conglomerates of the Millstone Grit and red sandstone and conglomerate of the Old Red Sandstone form a subordinate proportion.

(*b*) *Hunts Bay.*

The relations of the Glacial deposits with the underlying *Patella* Beach are clearly displayed in a small cove on the eastern side of the Bay (Pl. XV, Figs. 1 and 2), where the succession is as follows :—

(iv) Thin impersistent Glacial gravel, with a capping of buff loam. Limestone pebbles are very rare or completely absent.

(iii) Irregular earthy unconsolidated head-like material, composed chiefly of angular and sub-angular fragments of Carboniferous Limestone, but containing also abundant fragments of black and grey cherts and partly silicified platy shales, together with fragments of rottenstone; the latter contain D_3 fossils. This deposit, reaching a thickness of 12 feet, is sharply divided from

(ii) Fine-grained fox-red roughly stratified sand and loam, containing no angular fragments of Limestone through its major extent, but with strings and threads of erratic pebbles and chips, chiefly of Millstone Grit cherts and shales; Coal Measures sandstones and Millstone Grit quartzites are also fairly common. The stratum is in the form of a lenticle, reaching a maximum thickness of 8 feet. Traced laterally, it is replaced by, and perhaps inosculates with, a coarse compact head with interstitial red loamy sand. This rests on an eroded surface of

(i) *Patella* Beach and *Patella* Beach platform.

There is then in this cove incontrovertible evidence of three types of Glacial deposit.

The stratified red loam, of very similar appearance to that occurring elsewhere (as at Eastern Slade and in the guts to the west of Kilboidy), is obviously not an æolian deposit, and its origin is to be attributed to fluvio-glacial agency, since it contains bedded strings of Upper Carboniferous erratic rocks. Similarly, the chaotic pile of head-like material cannot be considered a local scree, for there is complete mixture of the Limestone fragments with cherts, silicified shales, and rottenstones. The peculiar limitation of this uncemented breccia to the hollow immediately at the foot of the western side of Pwll-du Head is not without significance, for on the surface of the plateau above there is, according to the Survey Officers, a small pocket of clay with rottenstones, fine-grained black limestones, and cherts; some of the fragments contain a D_3 fauna, while crystals of wavellite are not uncommon. This pocket is in an anomalous position, for it lies within about 20 feet of the base of the Lower Dibunophyllum Zone; to account for its presence, the Survey Officers, avoiding the suggestion of unconformity, considered it to have "either been let down by a fault or have subsided in a swallow-hole". There is, however, not the slightest evidence for either of these suppositions, or for that of unconformity: the stepped scarps of the D_1 pseudo-breccias are sufficient witness against such structural relations. It is true that there are abundant fragments of black shales and rottenstones, but many of these are rounded; they are set in a loamy matrix; and they are accompanied by an indiscriminate mixture of Upper Carboniferous grits and sandstones. In other words, the pocket is without question a pocket of Glacial gravel, in which the D_3 rocks and the associated Millstone Grit cherts happen to be unusually abundant. These last may have been derived from the Llanrhidian-Bishopston-Oystermouth outcrop, or from the Oxwich syncline, or from the Port Eynon syncline. Both the latter may be eliminated, as it is highly improbable that ice moving from those areas,

necessarily travelling in a direction more or less southward, would climb nearly 300 feet to the summit of Pwll-du Head ; neither would it carry Coal Measure boulders. It is concluded that the ice travelled almost due south, bringing with it a locally abundant suite of North Gower rocks. It may be added that further east, in Brandy Cove, Caswell Bay, and Langland Bay, where the topographical evidence strongly favours the view that the Glacial deposits are derived from the north, the gravels also contain common fragments of Millstone Grit shales and D_3 rottenstones.

The location and constitution of the Glacial breccia on the shore beneath this pocket then make the conclusion unavoidable that it is derived from this proximate source, probably by solifluction—a process that could have functioned only when the neighbourhood was more or less free from a covering of ice ; yet the breccia rests on fluvio-glacial gravel and is overlain by Glacial gravel. The deposition of the ice-borne drift was at this locality, therefore, not continuous, but was interrupted by a (probably minor) oscillation of the ice-front, a condition of affairs repeated, but less clearly, near Rotherslade, in the guts to the west of Kiboidy, and in Rhossili Bay.

In the main expanse of Hunts Bay (Fig. 2) there is a comparable sequence, though the deposits cannot be traced laterally from the eastern cove owing to the intervention of a Limestone buttress. The red loam is impersistent and devoid of erratics. It is overlain by unconsolidated head banded with loamy sand near the base and containing interstitial sand throughout ; this head is composed almost wholly of local Limestone fragments, the abundant cherts and shales of the eastern cove being rare, owing to the barrage of the Limestone brow ; the two breccias, however, correspond otherwise in stratigraphical position and lithological character. Furthermore, the even upper surface of this deposit, and its presence at too great distances from the massive Limestone cliffs, lend weight to the view that it cannot be purely local scree, and is not the product merely of frost action. The conclusion is important, for it suggests that in several other cases, where impure head occurs, the anomalous nature of the sediments is to be attributed to the type of ice-and-water action that is described as solifluction in a later section, rather than to the incorporation of derived drift talus. The frequent presence of much sand and loam in the head is also more easily explained on such a hypothesis.

Above this Glacial breccia, sharply demarcated, there occurs typical South Wales gravelly drift in the form of a shallow pan, thickest (about 12 feet) in the middle of the Bay, but thinning out and disappearing towards the flanks. Such a lenticular shape, as also in the case of the fluvio-glacial loams of the eastern cove, strongly implies derivation down the gully of Deep Slade—i.e., from the north. The great majority of its pebbles, as usual, consists of Upper Carboniferous sandstones (including Millstone Grit quartzites and

conglomerates), with some Old Red Sandstone types, all pointing to a northern source. Lower Carboniferous rocks are absent. On the other hand, there also occur very rare specimens of rock-types that are of a more distant origin ; these include Triassic conglomerate, soda-felsite (probably from the Lleyn Peninsula), quartz-dolerite (probably from North Pembrokeshire), pink granite, fine-grained basalt or andesite (? from North Wales)—all suggesting a western

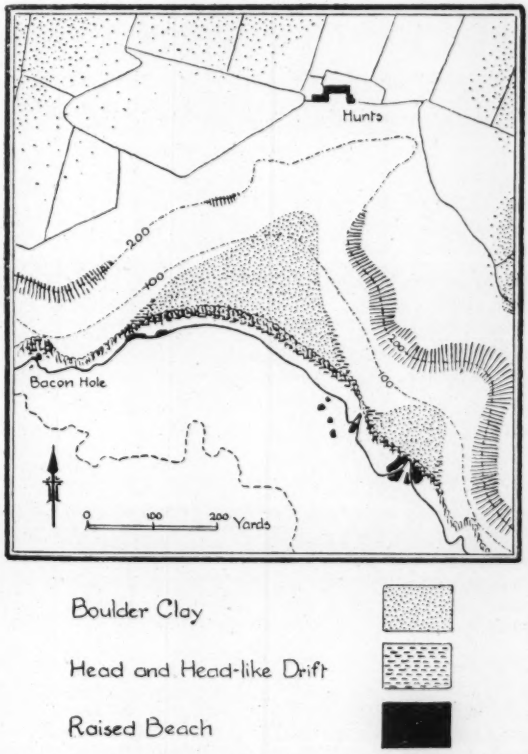


FIG. 2.—Map of Hunts Bay, showing the distribution of the superficial deposits.

or north-western source. It will be recalled that the Survey Officers [1] recorded the presence of igneous rocks in the drift of localities further east.

(*c*) *Hunts Bay to Shirecombe.*

In most of the guts along this stretch of coast, the *Patella* and *Neritoides* Beaches, and the overlying blown sands, are generally

[1] "The Country around Swansea": *Mem. Geol.*, op. cit., 1907, 140.

covered by cemented head; this consists of angular fragments of Carboniferous Limestone with little or no foreign erratic pebbles for the most part, though occasionally pockets of almost "pure" Glacial gravel are incorporated and cemented with the Avonian material. The head in places extends to levels below that of the neighbouring *Patella* Beach, or *Patella* Beach platform, and thus could have accumulated only after the latter had been formed and elevated—that is, it cannot be considered as contemporaneous with the Beach, and is not a member of the "raised beach series".

(*d*) *Oxwich Point to Horton.*

Between Oxwich Point and Eastern Slade, the Limestone cliffs, rising steeply to the plateau surface some 200 feet above, are separated from the shore by a narrow terrace, 100–150 yards wide, that terminates seawards in a line of low cliffs, 10–25 feet high. Towards the west, in Slade Bay, the deposits comprising this terrace consist of "pure" Glacial sand and gravel, from which fragments of Avonian rocks are wholly absent. This drift would appear, as Wilkinson observed, to have found its way down the little valley of Eastern Slade from the plateau above (which is drift-covered), and in order to account for its extension to Oxwich Point, Wilkinson[1] further suggested that there was an eastward trend in the direction of movement of the ice, in support of which he remarked that the material gets finer eastwards and becomes a loam. This last observation does not express the whole truth. On topographic grounds it would certainly appear that the Glacial gravels of Eastern Slade reached their present position by movement from the north *via* the little valley. Further, it is found that this coarse drift is wholly confined to the entrance of the valley, and extends not at all to the east: that is, the material of the terrace does not grade in the manner suggested by Wilkinson, and the gravel is a strictly local product—the outpourings of a tiny valley glacier; and the apparent grading is due to a replacement of the truly Glacial deposit by material of different origin. In support of the contention that it is derived from a northerly source, there is present in the Glacial gravel the typical suite of South Wales erratics—particularly Coal Measure sandstones, grits, and ironstone nodules, and Millstone Grit quartzites. Thus far, the evidence of topography, superficial extent of the drift, and rock assemblage is wholly consistent. But there occur, scattered through the gravel, occasional pebbles of Protozoic and igneous rocks, in total reaching a considerable number, but of course forming only a minute proportion of the whole. These include the following types: porphyritic soda-felsite (probably from the Lleyn Peninsula), quartz-porphyry (probably Lleyn), felspathic grit (probably Lleyn), devitrified vesicular rhyolite

[1] "West Gower and the Country around Pembrey": op. cit., 37, 41.

(similar to some of the Skomer rocks), crushed biotite-granite (? Dimetian), epidiorite or hornblende-schist (from Anglesey or Scotland), gneiss (? Anglesey), ophitic dolerite (? Dimetian), riebeckite-micro-granite [1,2,3,4] (a typical specimen of the Ailsa Craig rock; this is the most southerly record of its occurrence), hornblende-porphyrite [1,2,3] (a typical Galloway rock), soda-granophyre [2,3,4] (also Galloway), quartz-hyperite [1,2,3,4] (also Galloway), hornblende-diorite (also Galloway), epidotized basalt. These far-travelled erratics lie in the same matrix as the Upper Carboniferous material, and there is no stratigraphical discrimination between a deposit with northern erratics and a deposit with western and north-western erratics. There is thus an anomalous commingling of pebbles derived from very divergent sources: a state of affairs reminiscent of, but more striking than, that of Hunts Bay, and similar to others to be described.

It has already been remarked that the gravel, traced eastwards, is replaced by loam and head. There is no sharp break between the two deposits, however, and it is "impossible to draw a definite line between them". In the immediate neighbourhood of the gravel, the head consists of rather widely-scattered angular Limestone fragments in a coarse polygenetic sand composed of material very similar to that of the matrix of the gravel, with occasional pebbles of Upper Carboniferous rocks scattered throughout. Followed away from the gravel, the matrix of the head becomes finer-grained and increasingly homogeneous, until it finally partakes of the characters of the fox-red sandy loam in which the fragments are so often embedded. At the same time the occasional erratics become uncommon and finally disappear altogether. This transition occurs in a distance of 200 to 300 yards, after which the head, always remaining unconsolidated, continues essentially unchanged to Oxwich Point. Within the head, however, there are minor vagaries. The uppermost few feet are generally devoid of Limestone fragments, and the irregular line of junction between this fine loam and the underlying breccia is fairly sharp when viewed from a distance. The proportion of angular fragments may vary considerably, and in places the deposit may consist of breccia with little sandy matrix, while elsewhere it is wholly loam. Presumably for these reasons, Wilkinson considered the loam to be a deposit separate from, and newer than, the breccia, derived from some extraneous source: he described it as extending down into the latter in the form of

[1] Compare K. E. Williams, "The Glacial Drifts of Western Cardiganshire" GEOL. MAG., LXIV, 1927, 208, 213.

[2] Compare T. J. Jehu, "The Glacial Deposits of Northern Pembrokeshire". *Trans. Roy. Soc. Edin.*, lxi, 1904, 80, 81.

[3] Compare "The Country around Haverfordwest": *Mem. Geol. Surv.*, 1914, 219.

[4] Compare "The Country around Milford": *Mem. Geol. Surv.*, 1916 155, 156.

pipes. Actually, there is no piping of the breccia, but the sandy matrix surrounding the Limestone fragments is continued without interruption into the loam above, and consists of the same materials; it is evident that the two deposits are intimately related, and the origin of the loam is at least in part to be ascribed to causes involving the breccia, as will be adduced later.

In Eastern Slade Bay there is developed in places beneath the normal chaotic Glacial gravel a series of stratified sands and loams with strings and lenticles of erratic pebbles, the whole about 5 to 8 feet thick. These bedded deposits are obviously of fluvio-glacial origin, and are strongly reminiscent of the basal sands on the eastern side of Hunts Bay. Amongst the erratic pebbles are included igneous types from West Wales and Scotland.

In Horton Cove, slightly west of the foot of Western Slade, about 30 feet of very coarse breccia with massive angular Limestone blocks rests upon an Avonian foundation and flanks the cliffs behind. Irregularly scattered through the mass are abundant pockets of drift and solitary erratic pebbles, amongst which occur occasional igneous rocks. The deposit is thus not merely a local talus but has undergone some measure of transportation by ice, for neither the Limestone blocks nor the drift could have been introduced solely as a result of frost action; while the complete admixture of the two types of constituents in a sandy matrix also demands a more complicated process. The material may be compared with the breccia of Hunts Bay and with the deposits of Little Gut.

(*e*) *Overton Mere.*

The form of Overton Mere (Fig. 3) is almost an exact replica, on a slightly smaller scale, of Hunts Bay. The mid-portion of the mere is occupied by a spreading fan of Glacial gravel, of which the apex extends northwards along the cwm that leads from the shore to Overton Green. On each side of this pre-Glacial valley, the cliffs of Limestone rise steeply to the plateau level above, on the surface of which, particularly immediately north of Overton, are extensive tracts of sand and gravel. Shorewards, the fan terminates in a line of low cliffs, though gravel also partially underlies the modern storm beach. On the east and west sides the gravel, as at Eastern Slade and Hunts Bay, passes laterally into unconsolidated head. This consists of angular Limestone fragments, with a few Upper Carboniferous erratics, in an abundant matrix of fox-red sand that in places passes into an almost pure loam. As elsewhere, the topography and superficial extent of the drift thus strongly imply that the deposits have moved southwards to their present position along the obvious gap. The gravel at Overton Mere contains the usual suite of South Wales Upper Carboniferous erratics, amongst which are included abundant fragments of radiolarian cherts, banded

cherts, black shales, and rottenstones; these are derived almost certainly from the Port Eynon syncline, which extends westwards as far as, but not much further than, Overton.[1] They could not have come from the west, for such beds are not known to be appreciably developed in South Wales elsewhere than in Gower, along the North Crop of the Coalfield, and near Bridgend. But again, the far-travelled

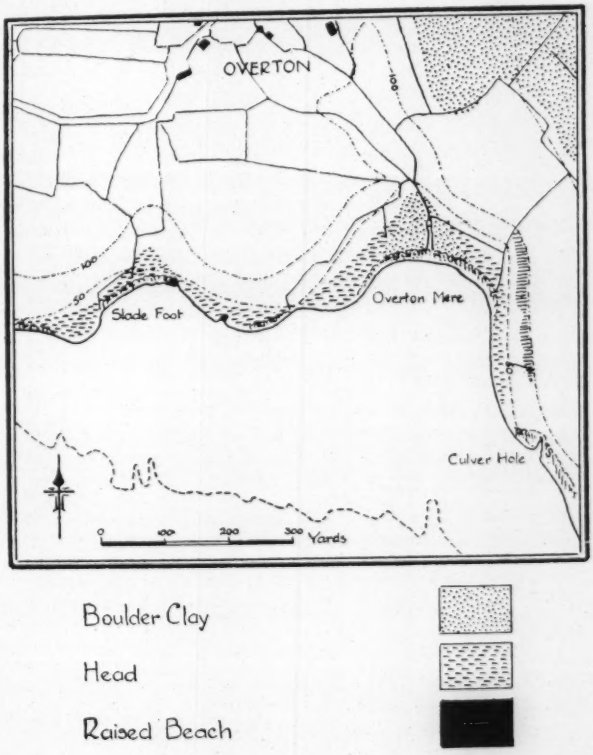


FIG. 3.—Map of Overton Mere, showing the distribution of the superficial deposits.

erratics appear, and in contiguity with these Upper Carboniferous rocks may be collected specimens of soda-felsite (probably Lleyn), quartz-porphyry (probably Lleyn), rhyolitic ash (? Lleyn), silicified dolerite (probably a Pembrokeshire type), biotite-granite (? Dimetian), acid pitchstone (comparable with the Arran dykes).

[1] T. N. George, "Studies in Avonian Brachiopoda: I. The Genera *Brachythyris* and *Martinia*": GEOL. MAG., lxiv, 1927, 117.

(*f*) *Overton Cliff to Fall.*

At the west end of Overton Cliff, in Little Gut, some 900 yards west–south-west of Overton Green, the shoreward portion of a long and deep precipitously-flanked cwm in the Carboniferous Limestone terminates in a line of uninterrupted low cliffs, about 12 feet high. These mark the limit of a narrow tongue of drift, which, as at Hunts Bay, Eastern Slade, and Overton Mere, extends for a short distance inland along the floor of the valley. Despite the steepness of the sides of the valley and its gorge-form, it is evident that the deposits of at least the mid-portion of the gut could not have attained their present position merely as frost-scree, for they are too far removed from any possible source of origin. Moreover, the nature of the deposits is opposed to an immediately local derivation, for they consist of abundant large angular blocks of Carboniferous Limestone in a coarse sandy matrix through which are promiscuously scattered rather less abundant pebbles of South Wales erratics, together with occasional far-travelled rocks; amongst the latter are included porphyritic soda-felsite (probably Lleyn), quartz-porphyry (probably Lleyn), epidiorite (? from Anglesey or Scotland), quartz-hyperite (a typical South Scottish type). There is a complete admixture of the constituents, which, together with the large size and position of the Limestone blocks, can only be explained by ice-transport.

In the gully below Longhole, the following succession is displayed :—

(v) Unconsolidated head of angular Limestone fragments in a red sandy matrix. About 12 feet.
(iv) Red loam, with strings and masses of angular fragments. About 4 feet.
(iii) "Pure" cemented Limestone head, with little interstitial loam. Impersistent, reaching about 1½ feet at a maximum.
(ii) Reddish loam with angular fragments of Limestone. Irregular, averaging about 2 feet.
(i) *Patella* Beach.

A small inlet some 200 yards east of Kilboidy shows a similar succession of alternating layers of loam and sporadically-cemented breccia, resting on about 8 feet of bedded sands with strings of erratic pebbles, comparable with the fluvio-glacial sands of Hunts Bay and Eastern Slade.

The form of a large gully 350 yards north-west of Kilboidy recalls Hunts Bay and Overton Mere, though on a much smaller scale. The steep cliffs of Carboniferous Limestone are here indented by an incipient valley, at the foot of which a fan-shaped accumulation of drift ends seawards in a line of low cliffs (Pl. XV, Fig. 3). The sequence is also similar to that of Hunts Bay and Eastern Slade. The upper portion consists of a coarse gravel, in which stratification is obscure, containing abundant Upper Carboniferous and a smaller proportion of Old Red pebbles and boulders. It contains, however, a very considerable proportion of angular and slightly-abraded

Limestone fragments, whose shape offers a marked contrast to that of the well-rounded erratics. There are also included uncommon pebbles of igneous and other far-travelled rocks, including porphyritic soda-felsite (probably Lleyn), quartz-porphyry (probably Lleyn), soda-porphyrite (probably Lleyn or South Scotland), quartz-hyperite (Galloway), hornblende-porphyrite (Galloway), Protozoic slate. The gravel, as at Overton Mere, Eastern Slade, and Hunts Bay, passes laterally into, and interdigitates with, uncemented head of angular Limestone fragments in a more or less abundant matrix of fox-red sandy loam. Beneath the chaotically piled gravel there occur about 8 feet of well-stratified red sands and loams, the junction of which with the gravel is clearly defined. They contain strings and lenticles of Limestone chips and abundant erratics, including igneous rocks.

A second large gully, some 200 yards north-west of the last, likewise recapitulates in miniature the essential features of Hunts Bay as regards both form and stratal succession. The mid-portion of the inlet shows about 20 feet of Glacial gravel, containing the usual abundance of arenaceous South Wales rock-types, but devoid of Avonian fragments. Igneous and Protozoic rocks are present, though rare ; they include soda-felsite (probably Lleyn), felsitic tuff (probably Lleyn), granophyre (probably Lleyn), epidiorite (probably North Wales). The gravel rests with a marked line of junction upon about 8 feet of fine-grained fox-red stratified sand with strings and lenticles of erratic pebbles and chips, corresponding in content and stratal position with the fluvio-glacial sands of Hunts Bay and Eastern Slade. On the eastern side of the gully, the Glacial gravel passes laterally into more or less unconsolidated head, with angular Limestone fragments and common erratics in a red loamy matrix. The head inosculates with the gravel in the form of wedges.

In Foxhole Slade (leading to Paviland Cave), near the Knave, in Ramslade, and in Butterslade, there are small residual relics of gravelly loam, in all of which igneous rocks may be discovered.

On the eastern side of Fall, bedded Glacial loams, with inclined irregular bands and strings of erratics, are banked against massive Carboniferous Limestone. They are overlain by, and merge upwards into, a chaotic uncemented breccia of angular Limestone fragments in a loamy matrix, through which variously-derived erratic pebbles and chips are promiscuously scattered ; amongst the latter are included igneous types. This head apparently passes laterally into, and contains pockets of, Glacial gravel consisting of Upper Carboniferous erratics in a coarse sandy matrix. On the western side of Fall,[1] a head of angular limestone fragments in a coarse red sandy matrix, devoid of erratics, merges downwards into a pure red loam, apparently unstratified, about 5 feet thick at a maximum.

[1] "West Gower and the Country around Pembrey" : op. cit., 38.

(*g*) *Rhossili Bay and Worms Head.*

The distribution of Glacial gravels on Worms Head is interestin and significant.[1] On the mainland, immediately south and soutl east of the Coastguard Station, the shore is fringed by a line of lo cliffs formed of uncemented head with few erratics. Immediatel opposite, at the eastern extremity of the Inner Head, a cliff of Glacia gravel, 6 to 8 feet high, extends westwards with a nearly flat uppe surface for some 50 yards. It then becomes fine-grained and cease more or less abruptly, being replaced by an almost " pure " Lime stone head that continues to fringe the foot of the hill to its wester extremity, where the Glacial gravel once more reappears for a fe yards. The neck joining the Inner to the Middle Head is devoi of superficial deposits, but on the east of the Middle Head the grave is again present over a small area, giving place laterally to head however, beneath the main mass of the hill ; this head continues t the neck joining the Middle to the Outer Head. On the east sid of the Outer Head, a small pocket of gravel lies beneath the disturbe relics of a kitchen-midden. Such peculiar distribution of the dri can only be explained satisfactorily on the assumption that th transporting ice-sheet or glacier approached the Worm from th north, so that the three hills formed buttresses protecting th southern flanks from the onslaught of the ice. Moreover, it is highl probable that this ice had little eastward component in its directio of movement, else some relic of its presence would almost certainl be preserved along the coast of the mainland below the Coastguar Station, where, in fact, nothing but head is present above th *Patella* Beach. Again, the rock-types present in the gravel show i to be a deposit identical with that of Rhossili Bay, which, as wil be shown, almost certainly is derived from the north and north-east

The Glacial deposits of Rhossili Bay, occurring as a low narro terrace bordering the foot of the Old Red Sandstone down,[2] hav been described in detail by both Prestwich [3] and the officers of th Geological Survey.[4] Over the main expanse, they consist of thre distinct and sharply separated layers :—

(iii) A rubble of angular fragments of red sandstone and conglomerate i a red sandy matrix. The material is obviously derived from th scarps of the Old Red Sandstone behind, and is a strictly loca product, erratics being absent. About 30 feet at a maximum.

(ii) Buff-coloured unstratified Glacial gravel, packed with more or les far-travelled boulders and pebbles. About 10 to 12 feet at a maximum.

(i) Red rubble, lithologically indistinguishable from the uppermost deposit About 5 feet seen.

[1] For details of distribution, consult T. N. George, op. cit., 1932, p. 314

[2] See T. N. George, op. cit., 1933, pl. xx, fig. c.

[3] J. Prestwich, " The Raised Beaches and ' Head ' or Rubble-drift of th South of England : Their Relation to the Valley Drifts and to the Glacia Period ; and on a late post-Glacial Submergence " : *Q.J.G.S.*, xlviii, 1892, 291

[4] " West Gower and the Country around Pembrey " : op. cit., 40.

Prestwich recorded the presence of a number of marine shells in the gravelly drift, and in consequence, hesitatingly referred it to the "Raised Beach". I agree with the Survey officers in denying its marine origin, and, as they did, I regard it as a typical Glacial product, agreeing in all essentials with the gravelly drift occurring over the remainder of the Peninsula. As the Survey officers point out, the deposit teems with erratics such as do not normally occur in such profusion in any of the ancient beaches. This gravelly drift is in the form of a very long wedge, and towards the south it thins and dies away, the upper and lower beds of rubble coalescing and forming one indivisible deposit. In the extreme southern corner of the Bay, the rubble gives place to typical Limestone head, of which some cemented blocks have tumbled on to the sandy shore below. The latter were considered by the Survey officers to be a representative of the "Raised Beach", but in no way do they conform with the shelly shingle of that deposit, and their formation is to be attributed to other than marine agency. The southernmost extension of the red rubble, a chaotic unstratified pile, is modified by the development of a crude banding, the layers being gently inclined towards the south-east, while there are included a notable proportion of sporadically-distributed Upper Carboniferous sandstones. It would seem that in this neighbourhood a small tongue of ice, moving from the landward side of Rhossili Down, spilled over the gully at the extremity of the hill and interfered with the normal formation of the rubble.

In this Bay, then, it is clear that there is "an example of the inosculation of two drifts of different origin. The upper and lower rubble-beds are strictly local deposits derived from the Old Red hills which overhang the bay, and are comparable to the local drifts which occupy the cwms in the Pennant region of the coalfield".[1] It may be added that the rubble is more readily comparable with the head of angular Limestone fragments that occurs in various localities further east, of which it is the exact physical counterpart in almost all respects, except that it is devoid of calcium carbonate and nowhere cemented. Indeed, its lateral passage into a Limestone head in the southern corner of the Bay, where Avonian rocks are faulted against the Old Red Sandstone, make the comparison inevitable. It follows, if this conclusion be true, that the insertion of the thin stratum of gravel was merely a brief interlude in the virtually continuous formation of the red rubble, the upper layer of which is thus only accidentally distinguished from the lower. That is, the formation of the rubble, and inferentially of much of the head elsewhere, was approximately contemporaneous with the advent of the gravel-transporting ice.

"The source of the gravel . . . can only be determined within wide limits. That it lay between north-east and north-west is proved

[1] Op. cit., 42.

by the abundance of Coal Measure boulders, and that it lay west of north may be inferred from the characters of the shells [recorded by Prestwich]." [1] Besides the Coal Measure boulders, there are present Millstone Grit quartzites and quartz-conglomerates, with an abundance of fairly large well-rounded boulders of black shale of Millstone Grit age. The latter are exceedingly brittle at the present day, and their abrasion and transport could have been effected only when they were frozen—a further argument against the deposit being a representative of the " Raised Beach ". They are fossiliferous, and include specimens of *Reticuloceras reticulatum* mut. β,[2] which occur in the corresponding zone of North Gower and of the North Crop of the Coalfield in a latitude east of that of Rhossili Bay. Associated with these shales are fragments of rottenstone, similar to that occurring at the top of the Avonian in the neighbourhood of Kidwelly and further east along the North Crop. As such rottenstones are unknown in Pembrokeshire, and occur in Gower no further west than the Port Eynon syncline, they strongly support the conclusion that the pebbles in the gravel are largely derived from a northern or north-eastern source. Moreover, in the gravel are subangular boulders and blocks of Carboniferous Limestone, which, unlike the remainder of the constituents, increase in size very markedly towards the northern end of the terrace of drift, suggesting that they are derived from a relatively near source to the north. They consist largely of Limestone of Z–C_1 age, such as is wholly absent from the western portion of the North Crop, but which can be matched exactly by strata outcropping along the northern coast of Gower between Burry Holm and Cheriton, and it is almost certainly to this neighbourhood that the source of the blocks is to be referred.

Thus far, then, the evidence is consistent in suggesting a southward movement of the ice. But the anomalous far-travelled erratics of western and north-western origin reappear, though rarely, to confuse the problem. They are scattered promiscuously throughout the gravel, and are not segregated into any particular layer: their mingling with the South Wales rocks occurred before the drift finally came to rest. They include soda-felsite (probably Lleyn), perlitic rhyolite (? Pembrokeshire), Valentian mudstone (? Haverfordwest district), hornblende-porphyrite (a typical South Scottish rock), quartz-hyperite (also South Scottish), Protozoic slate.

(*h*) *Inland Deposits.*

It is not proposed in the present paper to discuss in detail the various features displayed by the ground moraine over the plateau of Gower. It has already been remarked that exposures are rare, and the succession of deposits can be determined only infrequently. It seems clear, however, that the distinction between " Boulder

[1] Loc. cit.

[2] I am indebted to Mr. R. O. Jones for the identification of these specimens.

Clay" and "Gravel" made by the Survey officers is quite arbitrary, and very little if any true stony clay is developed in Gower; certainly there is no evidence for an upward succession of Boulder Clay followed by sand and gravel, such as is depicted on many of the hills of drift on the Survey map; on the contrary, the succession as seen along the coast is the reverse of this.

It is to be expected, however, that if movement of the drift were across Gower from north to south, and if this drift on the south coast contain far-travelled erratics, then such rock-types should occur in the drift of the plateau. Specimens have already been recorded from Rhossili and Reynoldston,[1] while new records include fine-grained pink biotite-granite (? Pembrokeshire) from near Paviland Farm; quartz-hyperite (a South Scottish rock), rhyolitic ash (? from North Wales), Protozoic slate, all from the "gravel" mound between Hills and Overton; felsitic tuff (? North Wales) from near Margam Farm; soda-felsite (probably Lleyn) from near Pennygoggy and Moorcorner; coarse rhyolitic tuff from Lake (Llanddewi); a typical fragment of St. Davids granophyre, from near Henllys; fine-grained porphyry (? North Wales), from Hangman's Pit; quartz-porphyry (probably Lleyn), from near Pitt Farm. The appended map (Fig. 4) shows the distribution of the far-travelled erratics in Western Gower, as at present known, though it is probable that any exposure in this district, if searched assiduously, and if the pebbly contents are sufficiently free from muddy covering, would yield samples. The map does not include records of (? Cretaceous) flints, which are ubiquitous, though sparsely scattered, in the drift. In Eastern Gower, no erratics have as yet been discovered on the plateau surface inland; their extreme rarity is in keeping with the variations in their lateral distribution along the coast.

III. The Origin of the Gravelly Drift.

The generally-held view concerning the Glacial deposits of Gower has been expressed by Strahan,[2] who considered that along the southern shores of the Peninsula (as also in the Vale of Glamorgan) there are evidences of two drifts of different origins, the one having travelled southwards and south-westwards from a northerly source, the other having moved eastwards along the Bristol Channel. While this broadly explains the distribution of erratics on the southern borders of the Coalfield, it does not give an adequate representation of the conditions in Gower, and its use by Sandford [3]

[1] F. T. Howard and A. W. Small, "Notes on Ice Action in South Wales": *Trans. Cardiff Nat. Soc.*, xxxii, 1901, 44.

[2] "The Country around Swansea": op. cit., 128, 139. "West Gower and the Country around Pembrey": op. cit., 40. A. Strahan, "The Geology of South Wales" in "Geology in the Field": *Geol. Assoc.*, 1910, 854.

[3] K. S. Sandford, "The Erratic Rocks and the Age of the Southern Limit of Glaciation in the Oxford District": *Q.J.G.S.*, lxxxv, 1929, 376. See also A. E. Trueman, "The Geology of the Swansea District": *Proc. Geol. Assoc.*, xxxv, 1924, 305.

in support of the contention that there are two drifts of different ages (the one from the west being the older, and possibly of pre-*Patella* Beach age) appears to be unwarranted.

It has been shown that in the eastern portion of the Peninsula between Oxwich Bay and Mumbles Head, the Glacial drift, a very

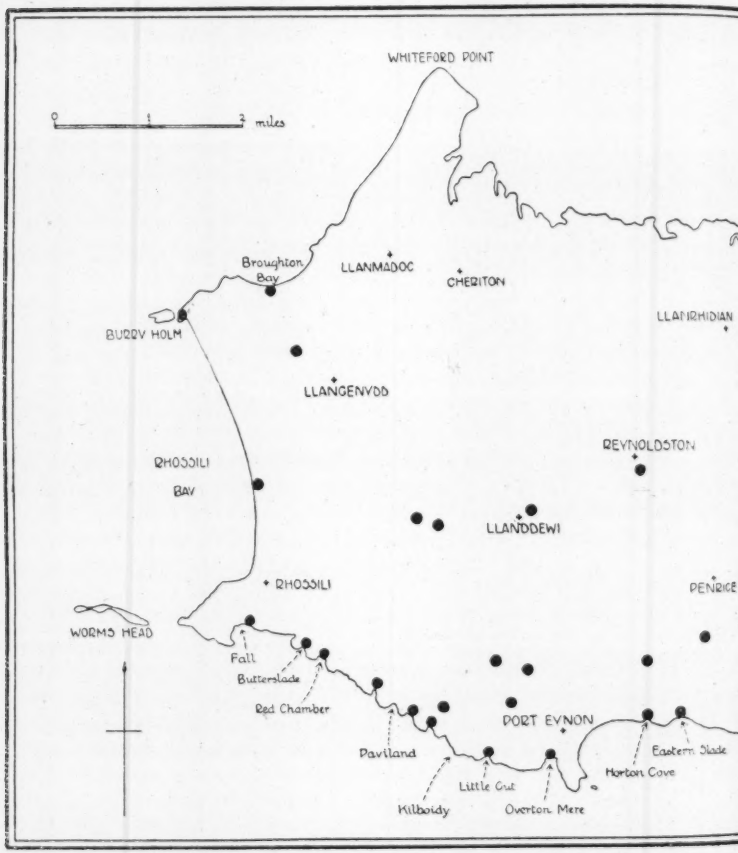


FIG. 4.—Map showing the localities in Western Gower where far-travelled erratics of western and north-western origin have been found. The occurrences of flint, apparently of Cretaceous age, are not recorded, as they are much too common to be indicated on such a small-scale map.

crudely stratified or chaotically piled gravelly deposit, consists of material that has been derived almost wholly from within the confines of the syncline of South Wales (including the Old Red Sandstone and Carboniferous Limestone of the North Crop). That

is, the transporting ice travelled in a general southward or south-westward direction from the Brecon Beacons, the Caermarthen Fans, and the Pennant uplands within the Coalfield.[1] Over this area pebbles foreign to South Wales, though present, are exceedingly rare. But over the western part of the Peninsula the drift, while remaining of essentially the same type as that of the eastern region, contains a relatively abundant suite of erratics foreign to South Wales, all of which indicate derivation from a distant western or north-western source. It is obvious that these have arrived at their present position by way of the Irish Sea, St. George's Channel, and the Bristol Channel. Nevertheless, it is equally evident that the drift in which they are at present found is of northern origin, and is largely derived from districts lying east of Kidwelly (that is from longitudes east of Rhossili) : this is shown not only by the contents of the deposits, but also by their distribution in the north-and-south valleys of the south coast. The presence of the far-travelled erratics is thus anomalous. There are two alternative explanations.

It is possible that the western erratics are the last relics of an earlier phase of glaciation, and were originally deposited in a drift of western origin previous to the arrival of the local South Wales ice, being secondarily incorporated within the latter as it traversed the area. But there is no evidence, either in Gower or elsewhere in South Wales, of such an extensive ancient drift. Certainly in the area now under consideration the South Wales drift everywhere rests directly on solid rock : there is never any distinction between an upper deposit with local pebbles and a lower with igneous pebbles.

The second alternative is that the arrival of the western erratics was approximately contemporaneous with that of the Welsh ice. This seems best to fit the facts. The evidence in other areas, provided by Jehu,[2] Williams,[3] and others,[4] amply demonstrates that the period of maximum glaciation of the Irish Sea Ice was one during which the greater part of Pembrokeshire, the shoreward fringes of Cardiganshire, and the western limits of Caermarthenshire were invaded and over-ridden by an ice-sheet that on its retreat left behind extensive tracts of ground-moraine ; this contains far-travelled erratic pebbles derived from precisely the same sources as those present in the Gower drift, while the latter also contains Pembrokeshire rock-types. It is manifest that the submergence of South-West Wales by this ice-sheet could have been accomplished only if there was a sufficient packing of the ice, and its extension

[1] See "The Country around Swansea" : op. cit., 138. "The Country around Ammanford" : *Mem. Geol. Surv.*, 1907, 189. "The Country around Carmarthen" : *Mem. Geol. Surv.*, 1909, 143.

[2] T. J. Jehu, op. cit., 53.

[3] K. E. Williams, op. cit.

[4] "The Country around Haverfordwest" : op. cit., 216. "The Country around Milford" : op. cit., 154. "The Country around Pembroke and Tenby" : *Mem. Geol. Surv.*, 1921, 195.

across the depression of Caermarthen Bay to Gower—a very short distance—is to be expected. It has been shown that the Upper Boulder Clay and gravels of Cardiganshire, which extend only as far south as the northern fringes of Pembrokeshire, are of the age of the Newer Drift,[1] and it will scarcely be contended that the Lower Boulder Clay of that area is not approximately of the same age as the Older Drift of South Wales, which is probably late Mousterian.[2] It is concluded, therefore, that the origin of the Gower drift is to be attributed to a coalescing of the Irish Sea Ice and the South Wales Ice, the former moving eastwards and south-eastwards, the latter, on the whole, south-westwards along the Gwendraeth, Loughor, and Tawe Valleys. Caermarthen Bay and the Loughor Estuary are then to be regarded as areas of congestion, where the two ice-flows met and commingled. The great preponderance of South Wales pebbles in the Gower drift is not necessarily to be taken as evidence of a corresponding overwhelming proportion of ice, however, and it is probable that each ice-sheet modified the direction of flow of the other. In this connection it is obvious that the gravelly wedge in Rhossilli Bay could not have been transported to its present position by ice moving along the grain of the country without interference and diversion by some extraneous force, which, it is suggested, was the ice from the west. Such a postulated mode of accumulation of the Gower drift explains the presence of the far-travelled erratic pebbles, their relative abundance in the western part of the Peninsula, and the direction of movement of the ice. It also conforms with the known developments of Glacial deposits in South and West Wales, both chronologically and spatially. And, above all, it does not demand a wholly hypothetical glaciation of pre-Older Drift Age and of extent as great as, if not greater than, that of the Irish Sea Ice at the maximum, for which no evidence is forthcoming.

It need scarcely be added that it is not implied that the whole of the neighbouring Irish Sea Ice was involved in this commingling with the South Wales material. On the contrary, it is probable that the extreme southern limit of the Older Drift of South Wales lay but a short distance beyond the shores of Gower, as is indicated by the feeble development of the deposits in most of the cwms, by the insignificant degree of ice erosion, by the evidences of minor terminal oscillation (as in Hunts Bay), and by the grading of the material from north to south in Rhossili Bay. A considerable proportion of the Irish Sea Ice may thus have travelled south of Gower, and so eastwards along the Bristol Channel, transporting little else than far-travelled erratics. Movement was possibly, though improbably, facilitated by a submergence of the land, so that the lower drift of Pencoed[3]

[1] J. K. Charlesworth, op. cit., 340.
[2] T. N. George, op. cit., 1932, 316.
[3] "The Country around Bridgend": *Mem. Geol. Surv.*, 1904, 100.

may have been deposited from ice-floes; but there is no evidence of a contemporaneous extensive marine transgression such as Sandford [1] has postulated. Incidentally, the succession at Pencoed, where normal South Wales drift overlies the drift of western origin, is not evidence of the latter being older than any local till,[2] for the upper deposit is of the age of the New Drift.

IV. The Head and the Associated Loams.

(*a*) *The Characters of the Head.*

Under the general term "head", it is evident that several different types of deposit have been included in the past. In some cases the material consists solely of angular fragments of Carboniferous Limestone without extraneous pebbles; where most clearly developed, as in sheltered coves and gullies, this is almost always concreted hard by calcium carbonate. Such a deposit is apparently similar in both form and origin to local scree, tumbled from nearby sources. In other cases, angular Limestone fragments are enclosed in a matrix of fox-red sandy loam. No rigid line can be drawn between this and a simple scree deposit, there being a gradual increase in the proportion of sand, with a corresponding decrease in the degree of cementation. Nevertheless, the contrast between the two is marked when the amount of sand becomes great, especially if a crude stratification occurs in the arrangement of the fragments, and the presence of such sand cannot be due to frost action alone. Frequently the sand is not promiscuously distributed throughout the head, but beds of pure sand, often several feet thick, may be interbedded with sandy or cemented breccia; but there is not necessarily any grading of the constituents, and the contained angular Limestone fragments may be promiscuously scattered through the sand. Occasionally, unbroken fragile shells of land snails are present in the head. In yet other cases, as in Horton Cove and Little Gut, the head is of appearance similar to the last-described, but there also occurs in it in appreciable proportion of well-rounded erratic pebbles, which may outnumber the Limestone fragments. Pockets of "pure" Glacial gravel are not uncommon in cemented head of many parts of the coast. The sand or loam that occurs interstitially in the head, or bedded under or between masses of Limestone fragments, is almost invariably of a bright fox-red colour, differing noticeably from the mottled greys and yellows seen in the various blown sands of the area. These characters of the head are largely found also in the Coombe Rock of Southern England, and the one has often been considered as the equivalent of the other, both as regards conditions of formation and as regards age.

[1] K. S. Sandford, op. cit., 377.
[2] Ibid., 376.

(*b*) *Conditions of Formation.*

The topographical distribution of the deposit frequently in steep-sided gullies, and the detailed lithology of the fragments, inevitably lead to the conclusion that it is of local derivation. This is strikingly demonstrated in the cove on the eastern side of Hunts Bay, where the D_3 rottenstones and the Millstone Grit cherts, derived from the summit of Pwll-du Head, are restricted to a width of some 100 yards, and do not trespass across a low brow of solid rock into the main expanse of the Bay. The earlier workers were agreed that the head is of local origin, but their interpretations of its mode of origin differed greatly. Thus Tiddeman [1] considered it to be a normal talus, " obviously fallen from the limestone crags above, and containing no other rocks. . . . It is always firmly cemented." He [2] also remarked that the head, together with the " blown sand " and the " raised beach " shingle, pass under the gravelly drift: " That their formation preceded the local development of Glacial phenomena admits of no doubt." The hypothesis that the head is ordinary scree is obviously untenable for several reasons,[3] amongst which the chief is the presence of the red loam. It is true that this loam was regarded by Tiddeman [4] as a wind-blown sand approximately contemporaneous with the later stages of the " raised beach " (that is, the *Patella* Beach), but the intimate association of the sand with the head, the erosion of the Beach shingle before the deposition of the sand (as near Rotherslade), the different degrees of cementation of the Beach shingle and the sand, and the contrast the sand displays to the obvious blown sands, both recent and ancient, of the same area are factors all opposed to this view.[5] The comparison of the head with the Coombe Rock is doubtless pertinent, but Reid's [6] conception of the formation of the latter is scarcely applicable to Gower, where the deposit obviously cannot be attributed to pluvial action. Similar remarks apply to Ussher's [7] theory of the formation of similar breccias in Cornwall, while Prestwich's [8] conception is highly improbable.

[1] " The Country around Swansea ": op. cit., 118.

[2] " West Gower and the Country around Pembrey ": op. cit., 36.

[3] J. Prestwich, op. cit., 322 ff., where there is a discussion of the various theories.

[4] " The Country around Swansea ": op. cit., 119. " West Gower and the Country around Pembrey ": op. cit., 36.

[5] It need scarcely be remarked that some of the sands that overlie the " raised beach " and underlie head are true aeolian deposits. See T. N. George, op. cit., 1932, 310. But these are very different from the red loams associated with the head, which Tiddeman also regarded as wind-blown.

[6] C. Reid, " On the Origin of Dry Chalk Valleys and of Coombe Rock ": *Q.J.G.S.*, xliii, 1887, 364. Reid's theory is probably quite inadequate to explain the formation of Coombe Rock, which is also probably to be attributed to a process of solifluction, as demonstrated by F. H. Edmunds, " The Coombe Rock of the Hampshire and Sussex Coast ": *Summ. Prog. Geol. Surv. for* 1929, pt. ii, 1930, 63.

[7] W. A. E. Ussher, *The Tertiary Geology of Cornwall*, 1879, 42.

[8] J. Prestwich, op. cit., 329 ff.

The nature of the deposit in Gower seems best explained by the process that Andersson[1] has called solifluction. The essential conditions under which this process operates require a considerable rainfall or snowfall in a rigorous climate. The area, more or less free from a covering of ice, received heavy deposits of winter snow, much of which melted in summer. The broken surface of the ground then became in effect a sponge, of which the interstices were filled with slush and mud, the whole being fluid and moving downhill. A repetition of the process year after year enabled very considerable quantities of material to be transported in this way for some distance from the source of origin in a relatively short time. Each successive load, on reaching a final position of rest, formed a more or less clearly-defined unit, with the ultimate production of the appearance of stratification. Without its being contended that the layers of sand were strictly seasonal, it may at least be suggested that they are the products of more genial periods, when the snow-cap melted more rapidly or more completely than usual, so that the waters were of sufficient volume and power to carry away the finer-grained material and deposit it as small lenticles and fans when their speed was suddenly retarded on reaching the flat shore-platform below; in this connection the occurrence of sand as a basal deposit to the head in several localities is not without significance. Naturally such a mode of origin could be effective only where the slope of the ground was adequate for the gradual movement of the "earth-glaciers" downhill; it could not have occurred over the level surface of the plateau, and, in fact, that surface is singularly free from any extensive Pleistocene erosion when contrasted with the marginal cliffs.

The essence of this theory of solifluction demands ground that is largely ice-free. A blanket of ice would not only prevent the melt waters from finding an outlet through the earthy sponge beneath, but would also prevent the formation of the sponge itself, for to a considerable degree the larger fragments of the sponge result from weathering by frost action. For this reason it has been generally considered that solifluction proceeds at present beyond the ice-edge, while in the past it occurred before or after periods of glaciation,[2] or as an extra-marginal development. But the evidence in Gower shows that the process was in operation during the glaciation of the area at the time of the Older Drift. This is particularly evident at Hunts Bay, where, in the eastern cove, the earthy unconsolidated head overlies fluvio-glacial sands and underlies coarse gravel. This head contains a large proportion of Glacial erratics, amongst which are included pebbles that are derived from gravel at the summit of Pwll-du Head. That is, the ice that deposited the drift on Pwll-du

[1] J. G. Andersson, "Solifluction, a Component of Subaerial Denudation": *Journ. Geol.*, xiv, 1906, 91.

[2] W. B. Wright, *The Quaternary Ice Age*, 1914, 97.

Head had retreated by the time of formation of the breccia beneath, after which a re-advance of the ice occurred to deposit the drift in the main expanse of the Bay. A similar intercalation of head in drift is seen near Rotherslade, and in the guts to the west of Kilboidy, while in Rhossili Bay, on the other hand, the reverse relationship occurs, a layer of gravelly drift resting between two beds of rubble. Finally, the head which everywhere underlies the drift contains a greater or less amount of matricial red sand : it is contended that this sand could have been derived only from Glacial deposits, for the local Carboniferous Limestone is completely devoid of sand, which, in any case, could not be the product of frost action. The great quantity of sand in the head while larger erratic pebbles are often wanting is to be explained by the plateau form of the land surface, whereby the drainage, sufficient to carry the smaller grains, was quite inadequate to move the larger pebbles. All these considerations make it clear that as a whole the formation of head was approximately contemporaneous with that of the ground moraine, while there must have been notable minor oscillation of the ice-front, whose extreme southern limit was thus little beyond the shores of Gower. It would appear, therefore, that the distinction [1] between a lower head, devoid of Glacial erratics and older than the Older Drift, and an upper " post-Glacial " head, in which foreign pebbles occur more or less commonly, is unreal, quite arbitrary, and only very locally applicable stratigraphically.

It need scarcely be added that it is not implied that all the Limestone breccias occurring in Gower were formed either at the same time or under the same conditions as the head of Hunts Bay, of the coast in the Minchin Hole and Kilboidy neighbourhoods, of Eastern Slade, of Fall, and of Rhossili Bay. Thus at the period of the Newer Drift it is highly probable that conditions were propitious for a recurrence of the phenomenon, though it would be an exceedingly difficult matter to distinguish between heads formed at these different times in the absence of fossil evidence. Elsewhere the occurrence of shelly matricial sand, as at Caswell Bay and beneath the Middle Head of the Worm, implies an aeolian agency.

(*c*) *Cementation.*

Considerable emphasis has been placed [2] on the cemented or uncemented character of the head. Thus the breccia beneath the Glacial drift has been described as " always firmly cemented ", while the upper head is generally uncemented, the implication obviously being that as a whole cementation is a criterion of relative age. If the conclusions outlined above are true, then manifestly cementation is nothing of the kind. As a matter of fact, the breccia

[1] R. H. Tiddeman, op. cit., 1900, 443. A. Strahan, op. cit., 1910, 852.
[2] " The Country around Swansea " : op. cit., 118. " West Gower and the Country around Pembrey " : op. cit., 36.

beneath the gravels of Hunts Bay, at Eastern Slade, and in the guts to the north-west of Kilboidy is unconsolidated, whereas head with abundant erratics in Caswell Bay, at Heatherslade, and near Shirecombe is cemented hard. It is quite clear that the secondary infiltration of calcium carbonate has occurred sporadically at different times, and has been entirely dependent on local circumstances, such as faults, joints, and sub-surface drainage, irrespective of the age of the head.[1] It is also clear that the same concentration of salt-bearing waters will have a very different effect on a sand or a sandy head from that on a limestone scree.

V. The Upper Loam.

Most of the extensive exposures of head, and often of the glacial gravels, are capped by a thickness of fine-grained buff loam. This is very well developed along the southern flanks of the Inner Head of the Worm, and on the opposite mainland below the Coastguard Station; it is also present in force along the low cliffs between Horton, Eastern Slade, and Oxwich Point. At its maximum it may reach a thickness of 8 to 10 feet, but usually it is much thinner than this, though occurring thinly over almost the whole surface of the Peninsula where there is a development of soil. It is a remarkably homogeneous unstratified deposit consisting usually of fine particles of insoluble materials, but sometimes passing into a coarser sandy deposit, of which the individual grains are easily visible to the naked eye. It is nearly always soft and powdery. Its buff or yellow appearance is apparently due to the presence of ferruginous material (though it never possesses the deep red colour of the loams in the head). This description is sufficient to indicate its nature; it is a loess-like deposit accumulated under aeolian conditions.

Its source obviously cannot be assigned to the Carboniferous Limestone. Not only does it lie directly upon head and Glacial gravel, but its lower surface grades downwards into the Glacial and quasi-Glacial deposits, and it is difficult to distinguish sharply between them. It would appear that the period of formation of the head and the gravel (that is, the strictly Glacial period) was followed without great interval by the formation of the loam,[2] and the materials constituting the loam are largely derived from the older superficial deposits. It is thus similar to the loams in the head as regards the origin of its constituents, but differs as regards the agency of its formation.

Its effect would be to mask any irregularities in the surface; near Oxwich Point, for example, the corrugated surface of the unconsolidated breccia is not reflected in the summit of the platform by corresponding mounds and depressions. On the other hand, there

[1] Compare T. N. George, op. cit., 1932, 310.
[2] See W. B. Wright, op. cit., 204.

is no local piling of the loam in the form of dunes, and its upper surface is remarkably flat and would appear to have resulted from other than mere aeolian causes.[1]

EXPLANATION OF PLATE XV.

FIG.

1.—View of the cove on the eastern side of Hunts Bay. The platform of the *Patella* Beach, descending to levels below high water mark, is beautifully displayed; upon it rest cemented fragments of shelly shingle and conglomerate, seen in the foreground. The platform and the shingle are overlain by an elongate lenticle of fluvio-glacial sands containing strings of erratic pebbles; this underlies a thickness of uncemented breccia—an impure head. The col and gully clearly indicate the route taken by the Glacial deposits.

2.—A near view of the Glacial deposits in the cove on the eastern side of Hunts Bay. The abrupt demarcation of the lower stratified sands from the upper mass of chaotic breccia is well seen.

3.—The Glacial deposits in the large gully 350 yards north-west of Kilboidy. The lowest 8 to 10 feet consist of stratified sands and loams with few pebbles; they pass upwards into a chaotic pile of glacial gravel. The peculiar erosion channels are characteristic of this type of deposit.

The Sub-Bothnian Unconformity in Suodenniemi in Finland.

By J. J. SEDERHOLM, LL.D., Ph.D.

(For.M.G.S., Director of the Geological Survey of Finland).

ONLY lately did I become aware of a note *On the Sub-Bothnian Unconformity in Finland*, by Dr. William J. McCallien, in the June number for 1932 of the GEOLOGICAL MAGAZINE. May I be allowed here to answer his objections, which I think are based on insufficient observational material?

Dr. McCallien considers that the relations of the conglomerates of the Jaakkola region in Suodenniemi to the diorites, which I regard as belonging to their basement, ought to be explained in the same way as those of the Dalradian conglomerates in Ireland to the Donegal granite. He writes, "Just as in the Finnish occurrence, the Donegal conglomerates were for long thought to be resting unconformably on the Donegal granite. Now it is clearly understood that the granite is intrusive into the Dalradians."

In support of his opinion, McCallien relies mainly on two arguments. One is based on the existence of *current-bedding*, the other on the character of the *contact surface*.

THE CURRENT-BEDDING.

One of the localities in question is mentioned in the following words: "In the diagram drawn by Mikkola the bedding is drawn as if in places there had been current-bedding which had escaped

[1] See T. N. George, op. cit., 1932, 301.

Fig. 1

Fig. 2

Fig. 3

T.N.G. photo.

Glacial Deposits of Gower.

[*To face p.* 232.

notice. The curved bedding-lines which are drawn hint at the diorite being younger than the granulite. The section will, therefore, not furnish convincing proof of the pre-granulite age of the diorite until the details of the succession are worked out from the current bedding."

Now it so happens that this diagram was not drawn by Mikkola, but by myself. The lines indicate the bedding of the schist only in a schematical way, and there is certainly no current-bedding in the rock itself. Nor is current-bedding visible in the rocks of the neighbourhood. It is, therefore, absolutely impossible here to work out the succession in the way proposed. I refer to the photographs of the same rock in figs. 24 and 25 in my memoir.[1]

McCallien has observed current-bedding near to a contact at another place in the same area, but he admits that " the current-bedding is rather difficult to find " at this place. It cannot therefore be very distinct.

It therefore seems difficult to me, and I should think it would be to any unbiassed geologist, to believe that this single observation, recorded by a quite schematical drawing, could prove " without doubt " that the sediments nearest the diorite are, in the same way as in the Donegal area, younger than the sediments at a distance.

Unfortunately, McCallien's objection was not made when I was present at the place ; otherwise it would have been possible for me to discuss it in front of the outcrop.

Current-bedding is a very common phenomenon in Bothnian sediments. It is often well developed in the sandy layers of the varved schists at Lake Näsijärvi (cf. fig. 7 in *Bull. Comm. géol. Finlande*, No. 91). There, the varved structure makes it easy to determine which side originally lay upwards, but the current-bedding is itself so complicated that it would not be practicable to determine the position by its aid alone. At other places in the Bothnian areas, the relics of current-bedding have been so modified by movements and metamorphic changes, that it is impossible to say with certainty which side was originally the upper one. Such is the case in the feldspathic psammitic schist at Mauri, a locality that was visited during the excursion in question (*Bull. Comm. géol. Finlande*, 6, pl. v, fig. 1). I regard the structure here as representative of true current-bedding, but I am not able to determine its position with certainty. Another geologist (Sander) has even interpreted the phenomenon as due to tectonic movements.

At one place, I have myself observed current-bedding close to the contact between schist and breccia. This was at the much discussed locality at Lake Naarajärvi in Lavia. I have reproduced a photograph of this rock in Fig. 57 of my memoir, but the

[1] " On the Sub-Bothnian Unconformity and on Archaean Rocks formed by Secular Weathering," *Bull. Geol. Comm. Finland*, No. 95, 1931.

phenomenon is better seen in a schematical drawing, comprising a somewhat larger surface, in an earlier paper (*Geol. För. Stockh. Förh.*, 1915, fig. 8, p. 73). In the text I remarked (translated from the Swedish text) that the layers at some places were thicker, at others thinner, while bedding in great part was lacking in the layer which contained the pebbles, and that some layers had an oblique position, thus indicating a current-bedding (diskordant skiktning) of quite the same character as that occurring in the schists of North Lavia, south of the Välimäki conglomerate. There is nothing in the arrangement of this current-bedding, occurring next to the breccia, to indicate that the side of the formation in contact with the breccia might be the upper one. On the contrary, all the evidence here favours the conclusion that the breccia, which does not penetrate the schist, forms its basement.

I have, indeed, devoted so much attention to the occurrence in these rocks of current-bedding, of which I have published half-a-dozen drawings and photographs, that on the whole I do not think I can have overlooked any important circumstance.

The Character of the Contacts.

McCallien has stated that it is "not unusual for the diorite to send little tongues into the sediments". A small notch in the contact, such as shown in his schematical drawing of a contact exposure, proves absolutely nothing as to an intrusion. McCallien further says that my Fig. 19 "looks rather unlike a normal sedimentary breccia. It might be adequately explained if it were an intrusive breccia". I have never described it as a "normal" breccia, such as may be commonly found intercalated with other sediments. It is a rock which has received its brecciated character by weathering *in situ*, and its analogue is to be found only in the superficial parts of rocks in non-glaciated countries.

Now all those who have studied the region in any detail agree that it is not the diorite that shows the character of an intrusive rock at the contacts. I think that I have sufficiently refuted this argument in my memoir. No real dyke or vein has ever been found near the contacts. *It is the sedimentary rock which penetrates the diorite.* To explain this peculiar relationship the hypothesis of a palingenesis has been evoked. There are few geologists, if any, who have seen more of hybrid rocks, formed by an intimate mixture of an intrusive rock and sediments, etc., than myself, and I would insist that I have nowhere seen any analogue which would make it easy to explain the Jaakkola breccia as intrusive.

In his desire to solve all these complicated questions, mainly with the aid of the evidence of the current-bedding, McCallien fails to take into account my detailed description, illustrated by photographs and several analyses, of the northern contact between schists and highly-changed diorite. After rolling away many moss-carpets, I have stated that there is a gradual transition to be seen

between them which absolutely contradicts every assumption of an intrusion from the side of the diorite.

In a section near the house of the Civil Guards (figs. 14–15 in my memoir) the rock exposed is certainly a continuation of a layer of conglomerate which follows the contact of the Jaakkola diorite at a distance of only 70 m. The rock is a coarse conglomerate, with pebbles passing by gradation into gravelly material, and it lies at the northern side, while the sediment becomes more and more fine-grained as the southern side is approached. The southern side, nearest to the diorites must, therefore, be the upper one.

The evidence of the varved structures is, in general, much clearer and more indubitable than that of the current-bedding, and such evidence is everywhere in favour of the interpretation which I have advanced. In the area at Lake Näsijärvi, it has been the main evidence for determining the position of the layers.

The Evidence of the Meta-Basaltic Dykes.

If the gneissose diorite be of the same age as the post-Bothnian diorite, then it becomes impossible to explain how the gneissose diorite could have been cut by dykes of metabasalt (uralite-porphyrite), such as occur in several places, both at Jaakkola and in the Naarajärvi area in Lavia. This uralite-porphyrite has never been found to cut post-Bothnian intrusive rocks ; on the contrary it is often penetrated by the post-Bothnian intrusives. It certainly belongs to the upper part of the Bothnian, and the Jaakkola diorite cannot therefore be later than that.

It was, unfortunately, impossible, for lack of time, to visit during the excursion any places where the differences between the two diorites could be demonstrated. Whatever may have been the original material of the younger diorite, it is now clearly intrusive into the Bothnian schists (the uralite-porphyrite included) and into the older gneissose diorite. Because of the similarity of the composition of these two dioritic rocks contacts may in places be indistinct, but nevertheless there are contacts where the breccia belonging to the older diorite forms distinct fragments surrounded and veined by the younger one.

The Material of the Sediments.

The tonnage of dioritic pebbles in the conglomerates is overwhelmingly great ; amounting in the Suodenniemi-Lavia region to at least 100 million tons. Gravelly material, formed out of the decomposition of diorite, occurs associated with the conglomerates, and has sometimes the same character as dioritic portions of the contact breccias. Moreover, the more fine-grained parts of the schists are also largely composed of dioritic material right up to the actual contact with the diorite. Why is it then so difficult

to believe that this ever-present dioritic material, partly fresh, partly more or less decomposed and transported, should also outcrop as bedrock ? Along the southern contact of the schists we find, likewise, pebbles and gravel derived from the quartzitic and meta-andesitic rocks that outcrop to the south of the area of Bothnian schists.

I have personally devoted some three weeks to a preliminary survey of these rather small areas, and four weeks to their more detailed study ; Dr. Mäkinen has spent at least two weeks in similar studies ; and Dr. Mikkola devoted nearly four weeks of very efficient work to the mapping of this region. Each time the work has been tackled afresh new facts have appeared, especially as outcrops have been laid bare by stripping off the moss-cover. I do, of course, heartily welcome additional work, especially if it starts from a new point of view, but it will be necessary to pursue a new study in equal detail, and to check the new evidence against that found before which is consistently in favour of an opposite explanation. One observation of an indistinct current-bedding can hardly be regarded as convincing. For my part I think that whatever may be the importance of the observations on current-bedding in the Donegal area they will hardly play the same rôle in Suodenniemi.

The theoretical conclusions which I have drawn from the observations in this area have importance in two ways. The evidence points to the existence of Archaean rocks formed by weathering of plutonic rocks on an extensive scale ; and as a corollary of this conclusion it follows that an unconformity separates the sediments in question from their basement. As soon as it is proved that two plutonic diorites have existed in this area, and that the sediments contain abundant material formed by the decomposition of the older one, these theses can be regarded as proven, whatever may be the explanation of the Jaakkola breccia and the age of its diorite. But the field geology of the area, as well as its petrology, would seem to be full of contradictions if a systematic attempt were made to explain the contact relations of the Suodenniemi rocks in the same way as those of Donegal.

REVIEW.

THE BUSHVELD IGNEOUS COMPLEX OF THE CENTRAL TRANSVAAL. By A. L. HALL. Memoir No. 28, Geological Survey of the Union of South Africa. Pretoria, 1932. Price 10*s*.

THE Bushveld Igneous Complex is so widely known to petrologists, and is the subject of so voluminous a literature, no less than 184 items being listed in the bibliography of this work, that it is unnecessary in this place to give any general account of the problems that it presents. It only remains to welcome the appearance of an authoritative summary of the present state of our knowledge of this wonderful phenomenon, in a conveniently collected form, by so competent an authority. In addition to his numerous appreciative allusions to the work of the Shaler Memorial Expedition, Dr. Hall also pays a glowing tribute to that of the late much-lamented Dr. P. A. Wagner, as set forth especially in his admirable book, *The Platinum Deposits and Mines of South Africa*. It is, indeed, lucky for petrological science that the presence of the valuable platinum and chromite ores has so largely facilitated, by prospecting and development work, the purely scientific study of the complex. Indeed, the Merensky platinum horizon, never more than about 30 feet thick, but traceable for hundreds of miles along its outcrop, is one of the most remarkable of all known petrographical phenomena. It is perhaps useful to realize that the complex as a whole covers an area nearly as big as Scotland, and this is definitely a flattish intrusion with a floor as well as a roof and therefore not strictly comparable with the gigantic granite batholiths with no visible base. Furthermore, it is a lopolith, that is to say a laccolithic intrusion collapsed into a basin by reason of the upwelling of its own material to a higher level.

From a general consideration of the whole subject, it would seem that there is still a want of general agreement on three important points. These are : (1) the relationship of the Rooiberg formation to the Transvaal and Waterberg systems ; (2) the relation of the "Red Granite" to the norite lopolith ; and (3) perhaps the most difficult of all, the origin of the extraordinary "stratification" of the basic members of the complex. It may perhaps be doubted whether "rifting" is the happiest term that could be applied to this feature. After a careful consideration of all the views that have been put forward Dr. Hall obviously inclines to differentiation in situ rather than to separate intrusion of already differentiated partial magmas as the solution of this extremely difficult question, although on any view it is hard to see why the most basic layers come more or less in the middle of the succession rather than at the bottom. This almost necessarily seems to imply intrusion in at least two phases,

the later being emplaced above the earlier and its heavier constituents being arrested in their descent by the already more or less solidified or, at any rate, highly viscous top of the earlier one. This seems to be Dr. Hall's general idea. It appears probable that both crystal-sinking and re-fusion have been of importance and this is confirmed by recent studies of the chromite rocks.

The problem of the relative ages of the norite and the red granite is obviously very difficult, as is illustrated by the simple fact that Professor Daly came to two different conclusions in 1924 and 1928. The explanation seems to be that it is still rather uncertain how many different granites there are. Dr. Hall prudently remains seated on the fence, while apparently inclining to think that some of the granite may represent a re-melting and re-emplacement of part of an earlier intrusion : possibly even, in an extreme case, palingenesis of portions of the Old Granite of the Transvaal (which is almost always grey and not red at all) during the sinking of the Bushveld lopolith.

It is perhaps not generally realized that the Bushveld Complex also affords a magnificent example of thermal metamorphism, which is here described at length, but space will not permit of a discussion of this, or of the very full account of the platinum occurrences, which, of course, is mainly based on Wagner's work. Chapter xiv gives in about 14 pages an admirably clear summary of the geological history of the Transvaal region.

The Memoir is abundantly illustrated, with figures, 39 plates, both views of scenery and rock-sections, and a coloured map. As a minor point it is to be regretted that more care has not been devoted to proof-correction in so important a work. Printers' errors occur on nearly every page, and the occurrence of such words as " clacite " and " zicron " in lists of minerals tends to destroy the reader's confidence in the accuracy of the statistical information in tables, etc., since there is no way of conjecturally restoring misplaced numbers. In some analyses every chemical symbol is printed incorrectly. For example Feo is not the symbol for ferrous oxide and Co_2 is puzzling at first sight. However, the symbols for oxygen *are* letters, though of the wrong size, and not zeros throughout, as noticed in a recent American University publication.

After having thus relieved his editorial feelings, the reviewer desires to wind up by congratulating Dr. Hall on the completion after his retirement and after the labours of the International Congress of this masterly piece of work, which is destined to take a high place in the literature of petrology.

R. H. R.

CORRESPONDENCE.

RAISED BEACHES IN GOWER.

SIR,—I have read with great interest Dr. George's recent paper on the raised beaches and associated deposits in Gower, South Wales (*Proceedings Geologists' Association*, 43, pt. 4, 291–324), and one of the more important results of his work is the confirmation of the fact that there is more than one raised beach in that district, with which point I am in entire agreement.

There appears, however, to be considerable confusion as to the distinguishing features of his various stages, the descriptions of which are vague and misleading. For instance, although the fauna he reports from his *Patella* Beach and from the *Neritoides* Beach is that of the present shore, he calls the one cold and the other warm (p. 317). Again, the fauna which he lists on p. 297 is almost, if not quite, an ecological impossibility: if it is considered to have lived near the snouts of the valley glaciers described on p. 297, therefore the erratics found in the beach have been derived from glaciers which existed before the formation of this beach.

His confusion about my 30 ft. beach of southern England is quite needless. This raised beach, which can be seen at many places along the south coast, can be defined as showing a positive movement of about 30 feet, as containing a fauna slightly colder than that of the present day, and from the stratigraphical point of view, being interglacial in the sense that it is earlier than at least part of the head, but contains derived erratics. Contemporaneous with this beach are shingle banks up to about 50 feet at some places, as at Portland, in the Isle of Wight, and in Sussex, and it has been traced by Professor Palmer and Colonel Cooke into river gravels containing implements of approximately Mousterian date. In face of this definition this beach cannot be correlated with any pre-glacial beach.

If, therefore, Dr. George insists that his *Patella* Beach is pre-glacial, then it is certainly not contemporaneous with the 30 ft. beach of southern England; but it seems far more likely that the main 25 to 30 ft. beach in Gower, whose height I have measured at several points, is contemporaneous with the 30 ft. beach of southern England: we then arrive back at our original contention that Dr. George's *Patella* Beach is in no sense pre-glacial. In the unfortunate absence of a critical fauna in Gower, it is not possible to suggest a very definite correlation of either the *Patella* or the *Neritoides* Beach with the 30 ft. beach of southern England, but as these two beaches described by Dr. George appear to be very close in height, it must be a matter of extreme difficulty to distinguish them, at least on the open coast away from the caves.

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OXFORD.
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